Table of Contents

Table of Contents i
Acronyms and Abbreviations v
Executive Summary vii
1 Overview 1-1
1.1 Results of Stakeholder Meeting 1-2
1.2 Stakeholder Needs 1-3
1.2.1 1. Transit Providers – DASH, WMATA and Fairfax County Connector 1-3
1.2.2 City Traffic – Traffic Management Center. 1-4
1.2.3 City Traffic – Traffic Signals. 1-4
1.2.4 City Transportation Planning 1-5
1.2.5 City Parking 1-5
1.2.6 Alexandria IT 1-5
1.2.7 City First Responders – Alexandria Police, Alexandria Fire, Arlington county Fire, Fairfax County Fire 1-5
1.2.8 City 911 Center 1-6
1.2.9 Arlington County 1-6
1.2.10 VDOT NRO 1-6
1.2.11 MW COG Transportation Planning Board 1-6
2 Existing ITS Infrastructure 2-1
2.1 Ongoing Projects 2-1
2.2 Traffic Signal Systems 2-2
2.3 CCTV Camera Surveillance. 2-7
2.4 City Traffic Management Center TMC 2-10
2.5 Communications System 2-12
2.6 City Parking 2-15
2.7 DASH Transit Technologies 2-16
2.8 Roadway Weather Information System (RWIS) 2-17
2.9 Other Electronic Information Devices – Flashing Beacons, Radar Signs and School Zone Beacons. 2-17
3 Current Practices in Other Jurisdictions 3-1
3.1 VDOT Northern Region Operations (NRO) 3-1

3.2 Arlington County 3-2
3.3 Montgomery County, Maryland 3-5
4 Near Term Deployments 4-1
4.1 Transit Signal Priority (TSP) 4-2
4.1.1 Overview 4-2
4.1.2 Technology Options 4-2
4.1.3 Expansion Criteria 4-2
4.1.4 Conclusions and Recommendations 4-3
4.2 Adaptive Traffic Signal Control (ATSC) 4-3
4.2.1 Overview 4-4
4.2.2 Technology Options 4-4
4.2.3 Corridor Options 4-5
4.2.4 Conclusions and Recommendations 4-6
4.3 Traffic Signal Systems 4-6
4.3.1 Overview 4-6
4.3.2 Technology Options 4-6
4.3.3 Conclusions and Recommendations 4-7
4.4 Advanced Transportation Management Systems 4-7
4.4.1 ATMS Selection Criteria 4-8
4.4.2 ATMS Subsystems and Capabilities 4-8
4.5 Detection Options 4-11
4.5.1 Vehicle Detection 4-11
4.5.2 Pedestrian Detection 4-12
4.5.3 Bike Detection 4-12
4.6 Controllers 4-13
4.6.1 Controller Options 4-13
4.6.2 Controller Replacement Plan 4-13
4.7 Cabinets 4-14
4.7.1 Cabinet Options 4-14
4.7.2 Cabinet Recommendations 4-14
4.8 Closed Circuit Television (CCTV) 4-15
4.8.1 Overview 4-15
4.8.2 Recommendations 4-15
4.9 Communications Backbone 4-17

4.9.1 Overview 4-17
4.9.2 Technology Options 4-18
4.9.3 Recommendations 4-19
4.10 Traffic Management Center .... **Error! Bookmark not defined.**
4.10.1 Traffic Management Center Requirements. 4-21
4.10.2 Conditions Map Alternatives. 4-22
4.10.3 Monitor and Control Alternatives. 4-22
4.10.4 Future Operational Needs. 4-24
4.11 Parking Management 4-26
4.12 Information Devices (RWIS, Variable Message Signs, Beacons) 4-27
4.12.1 Road Weather Information System (RWIS)...4-27
4.12.2 Variable Message Signs 4-28
5 Future Deployments 5-1
5.1 Overview 5-1
5.2 5.2 Connected and Autonomous Vehicles (CAV) 5-2
5.2.1 Overview 5-2
5.2.2 AV Technologies 5-2
5.2.3 CV Technologies 5-4
5.2.4 Policy and Planning for Connected and Autonomous Vehicles (CAV) 5-4
5.2.5 CAV Recommendations...5-7
5.3 Bike and Pedestrian Applications..5-7
5.3.1 Overview 5-7
5.3.2 Technology and Applications Options...5-8
5.3.3 Recommendations 5-10
5.4 Putting it All Together – Smart Cities 5-10
5.4.1 Overview 5-10
5.4.2 Recommendations 5-12
6 Implementation Plan 6-1

Figures

Figure 2.1	Fiber Installation Plan.
Figure 2.2	Signals without Communications / Signals without Pedestrian Signals.
Figure 2.3	CCTV Location Map.
Figure 2.4	Copper Assets.
Figure 2.5	On street metered parking
Figure 2.6	Comprehensive Equipment Map
Figure 4.1	Proposed Adaptive Traffic Signal Control corridors.
Figure 4.2	Average Speeds, 5:00 PM October 2017. Source: RITIS Vehicle Probe Module
Figure 4.3	Concept System Architecture
Figure 4.4	Recommended TMC Staffing
Figure 4.5	Organization Chart
Figure 4.6	Inclement Weather Crash History
Figure 5.1	SAE and NHTSA Levels of Vehicle Autonomy
Figure 6.1	Implementation Schedule of Projects and Procurements

Tables

Table 2.1	Cabinet Channels
Table 2.2	Firmware Installs
Table 3.1	Comparison of Arlington County and City of Alexandria ITS
Table 3.2	Summary of ITS Investments Montgomery County, MD
Table 4.1	Potential Transit Signal Priority Corridors
Table 4.2	Controller Inventory
Table 4.3	Cabinet Specifications
Table 4.4	CCTV Camera Current and Planned
Table 4.5	Typical ATMS Vendor Modules
Table 5.1	NCHRP Report 845 Strategies
Table 6.1	Sources and Uses of Funds ($K)

Acronyms and Abbreviations

AD - Archived Data

ASC – Actuated Signal Controller

APTS Advance Public Transportation Systems

ASC Actuated Traffic Signal Controller

ATIS – Advanced Traveler Information System

ATMS – Advanced Traffic Management System

ATSC – Adaptive Traffic Signal Control

AVL – Automated Vehicle Location

BRT – Bus Rapid Transit

CAD – Computer Aided Dispatch

CCTV – Closed Circuit Television

CFR – Code of Federal Regulations

CHART – Coordinated Highway Action Response Team (Maryland)

CMS Congestion Management System

CMU – Conflict Monitor Units

CVO - Commercial Vehicle Operations

DCM – Data Collection and Monitoring

DMS – Dynamic Message Signs

DSRC - Dedicated Short Range Communication

EM - Emergency Management

EMA - Emergency Management Agency

EMS - Emergency Medical Services

EOC - Emergency Operations Center

FHWA – Federal Highway Administration

FMS - Field Management Stations

HAR – Highway Advisory Radio

HAZMAT - Hazardous Materials

HOV - High Occupancy Vehicle

ICS - Incident Command System

ICM - Integrated Corridor Management

ITS – Intelligent Transportation Systems

MWAA – Metropolitan Washington Airports Authority

NTCIP – National Transportation Communications for Intelligent Transportation System Protocol

NWS - National Weather Service

PCMS – Portable Changeable Message Signs

RITIS - Regional Integrated Transportation Information System

RWIS – Road Weather Information System

TDM – Travel Demand Management

TIM – Traffic Incident Management

TIP – Transportation Improvement Program

TMC – Traffic Management Center

TSP – Transit Signal Priority

USDOT – United States Department of Transportation

VDOT – Virginia Department of Transportation

WMATA – Washington Metropolitan Area Transit Authority

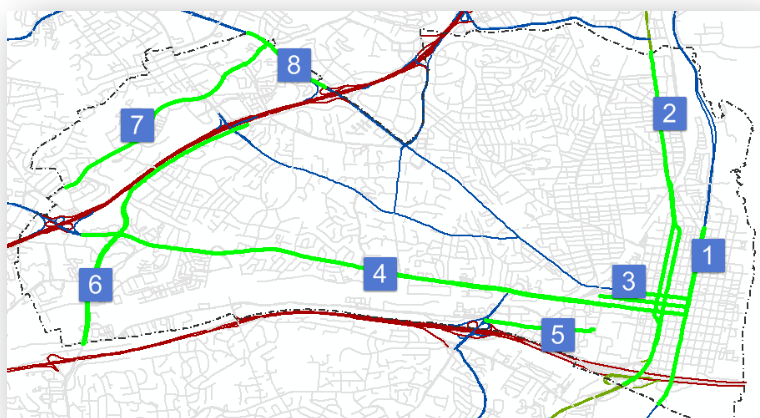
Executive Summary

The City of Alexandria currently has an operating Traffic Management Center (TMC), fiber optic connections to signals, and uses many Intelligent Transportation System (ITS) technologies. Although many elements and ITS technologies are in place, the City recognizes an ITS Master Plan is needed to best use the investments it has made, and to guide future efforts.

The goal of this ITS Master Plan is to *"Create a roadmap for future ITS deployments that is consistent with the City transportation management goals and objectives while leveraging currently deployed infrastructure."* To meet this goal a traditional 6 step process was used:

1. Determine the Mission and Goals for the Plan.
2. Review the Existing Signal, Communications and CCTV System.
3. Determine common practices in other communities and VDOT.
4. Identify and evaluate Near Term Deployments.
5. Identify and evaluate Long Term Deployments.
6. Create the Implementation Plan.

Figure ES-1 – Proposed Adaptive Traffic Signal Control corridors.



The process studied twelve (12) separate elements to determine existing technologies that will improve existing operations and provide a foundation for future technologies. The results of that analysis are the **Near-Term Deployments**:

1) Transit Signal Priority (TSP). TSP is currently being implemented in two corridors. Two additional corridors – King Street and Janney-Seminary are good candidates to extend the use of TSP.
2) Adaptive Traffic Signal Control (ATSC). Eight (8) corridors are planned to be upgraded to ATSC.
3) Traffic Signal Systems. An upgrade is recommended and the study developed criteria to select the upgrade.
4) Advance Transportation Management Systems (ATMS). As with the Traffic Signal Systems, the plan recommends the City upgrade their ATMS using criteria provided and a systems engineering approach.
5) Detection. The City uses a wide range of detection technologies. The study recommends the City continue this approach and base the detection method on site and traffic needs.

6) Controllers. The City should phase out the older EPAC 300 controllers with the Advanced Transportation Controller (ATC) standard. The new controllers will be placed on TSP and ATSC corridors.
7) Cabinets. New cabinets should continue to be the NEMA TS2 type. The City should adopt the Advanced Transportation Controller Cabinet (ATCC) only as the ATCC V2 standard matures, as VDOT migrates towards the ATCC, or for very specific applications. An ATCC installation to test this type of cabinet is recommended.
8) Closed Circuit Television (CCTV). There are currently 36 CCTV cameras in place or soon to be put in place. The City should add 31 more cameras to achieve close to full coverage.
9) Communications Backbone. Phase I-IV is ongoing and will place fiber along many key corridors. A new Phase V is proposed that will add two additional corridors and plans new connections.
10) Traffic Management Center (TMC). The plan recommends a robust TMC that is supported by the ATMS and off the shelf systems. Current staffing is below recommended levels; additional staff will be necessary to provide coverage during normal or emergency operations. On the following page Figure ES-2 shows the Conceptual Systems Architecture to integrate internal and external communications, data and systems.
11) Parking Management. Advanced Parking Management Systems (APMS) are evolving. The City's parking plans do not include an APMS. The City will be well served using electronic, web enabled metered parking to provide information to visitors.
12) Information Devices (RWIS, Variable Message Signs, Beacons). Permanent Variable Message Signs (VMS) are not recommended. Additional Roadway Weather Information Stations (RWIS) and communications to Portable Change Message Signs (PCMS) are recommended.

Future Deployments

This Master Plan – as well as the City's other planning efforts – envision separate, connected and easily used transit, bike and pedestrian modes. The City's Transportation Master Plan, Complete Streets Guidelines and ongoing efforts with Vision Zero emphasize the need for an attractive, well connected multimodal transportation system. The key question for ITS Future Deployments is how to best support this vision.

Connected and Autonomous Vehicles (CAV) are the future. The When, What, Where and How has not been decided, and there are many unanswered questions and obstacles. Nonetheless, numerous trials have shown that the technology is available. The Google self-driving car has been tested since 2009, and as of June 2016, has logged a total of 1,725,911 mi[1] in autonomous mode. Most automobile manufacturers plan on fielding semi-autonomous vehicles by 2021.

To prepare Alexandria for CAV, the Plan recommends:

1) Conduct regulatory review to fully understand what City or State Code impedes City CAV pilot projects.
2) **Conduct pilot of a CAV corridor** within the City and for eventual CAV deployment throughout the region. This pilot will need to be planned with the VDOT CV group. A shuttle service between high density nodes or transit hubs would provide a good pilot. There are two potential sites for the pilot – Eisenhower Avenue and Potomac Yards.

[1] Google Self Driving Car Project, Monthly Report June 2016.

The Eisenhower Avenue shuttle will provide connectivity to points between the Van Dorn Street (Blue Line) and Eisenhower Avenue (Yellow Line) Metro Rail stations. The shuttle would run along Eisenhower Avenue which has good access control and is not heavily congested.

The shuttle in Potomac Yards would provide access throughout the Potomac Yards and the planned new Blue/Yellow Line station.

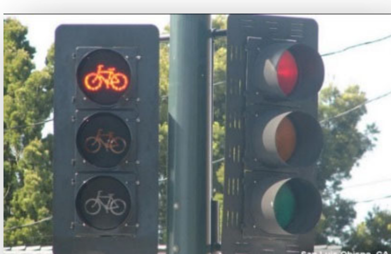
3) Work with the VDOT CV group to plan for eventual deployment of CV technology and applications within the City based on lessons learned from the VCC initiative.
4) Complete Installation of Fiber Optic cables and extend broadband communications capability to all signalized intersections and ITS devices.
5) Replace traffic signal controllers and roadside cabinets to meet the increased demands of Connected Vehicles and V2I.
6) Plan uninterrupted power supply (UPS) for intersections where DSRC radios may be deployed.

NCHRP Report 845, *Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*[2] was released in late 2017 and lists strategies and actions that different levels of government can take. Of special relevance to Alexandria, the report identifies a number of local government strategies to encourage Shared Autonomous Vehicles (SAV). These vehicles will share riders and, like transit, reduce the number of vehicles on the roadways.

Alexandria Complete Streets Design Guidelines: Main Street Example

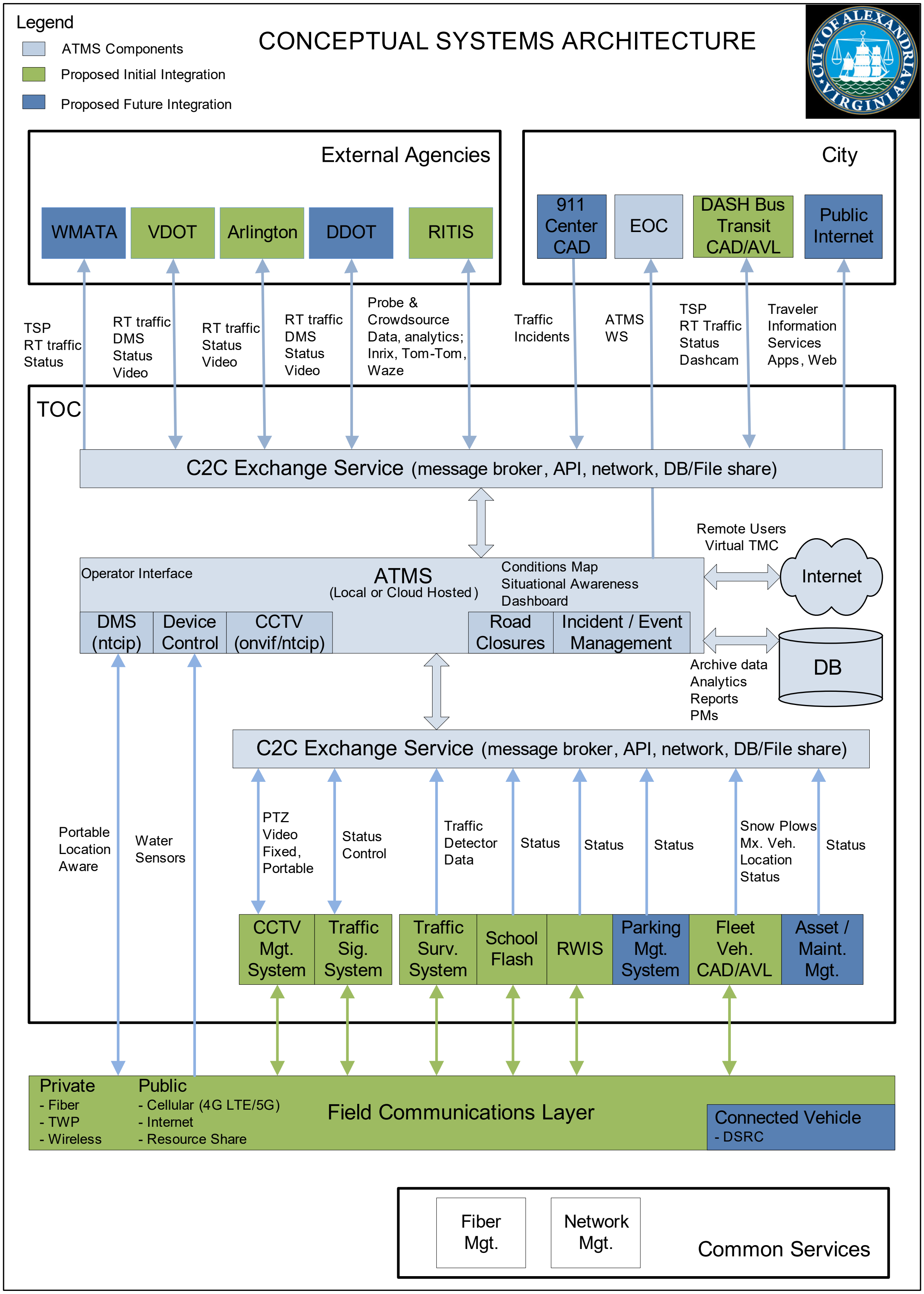
With fewer vehicles on the roadways and less demand for parking the City's Complete Streets concepts will be easier to implement. Complete streets, will in turn encourage bike and pedestrian uses. The Plan identifies a number of techniques and technologies to improve bike and pedestrian safety and capacity.

Although each technique and the technologies identified are appropriate for specific situations, improved detection is required for most. The plan recommends that a Systems Engineering approach be taken to identify active detection to be implemented.



The future also promises to bring improved efficiencies of city services and provide additional insights of collected data made possible via the Internet of Things (IoT) and the Smart Cities initiatives. Smart street lights which may also detect traffic and parking patterns and smart parking systems to improve parking space utilization and reduce circulation and congestion are all possible applications.

[2] Transportation Research Board, 2017. *Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*, NCHRP Research Report 845.


Legend
ATMS Components
Proposed Initial Integration
Proposed Future Integration
CONCEPTUAL SYSTEMS ARCHITECTURE
External Agencies
WMATA
VDOT
Arlington
DDOT
RITIS
City
911 Center CAD
EOC
DASH Bus Transit CAD/AVL
Public Internet
TSP RT traffic Status
RT traffic DMS Status Video
RT traffic Status Video
RT traffic DMS Status Video
Probe & Crowdsource Data, analytics; Inrix, Tom-Tom, Waze
Traffic Incidents
ATMS WS
TSP RT Traffic Status Dashcam
Traveler Information Services Apps, Web
TOC
C2C Exchange Service (message broker, API, network, DB/File share)
Remote Users Virtual TMC
Internet
Operator Interface
ATMS
(Local or Cloud Hosted)
Conditions Map Situational Awareness Dashboard
DMS (ntcip)
Device Control
CCTV (onvif/ntcip)
Road Closures
Incident / Event Management
Archive data Analytics Reports PMs
DB
C2C Exchange Service (message broker, API, network, DB/File share)
Portable Location Aware
Water Sensors
PTZ Video Fixed, Portable
Status Control
Traffic Detector Data
Status
Status
Status
Snow Plows Mx. Veh. Location Status
Status
CCTV Mgt. System
Traffic Sig. System
Traffic Surv. System
School Flash
RWIS
Parking Mgt. System
Fleet Veh. CAD/AVL
Asset / Maint. Mgt.
Private
- Fiber
- TWP
- Wireless
Public
- Cellular (4G LTE/5G)
- Internet
- Resource Share
Field Communications Layer
Connected Vehicle
- DSRC
Fiber Mgt.
Network Mgt.
Common Services

Funding Needs. The 12 Near Term Deployment recommendations correspond to a series of projects and procurements costing $44.8 Million. A future Phase VI adds an additional $4 million. Fortunately, the City has been successful obtaining Congestion Mitigation and Air Quality Improvement (CMAQ), Northern Virginia Transportation Authority (NVTA) funding and Smart Scale Funding for some of these improvements. The shortfall is estimated to be $11.7 Million. A summary of Elements and funding is shown in Table ES-1.

Table ES – 1 Funding Requirements

ITS Element	Unfunded	Total
TSP Duke/RT 1		$910
TSP King/Duke		$1,195
Phase I-III		$8,206
Phase IV Fiber		$2,126
Phase V Fiber	$2,543	$2,543
ATSC		$14,676
Eisenhower Broadband		$1,000
Bike Ped	$4,950	$4,950
Other	$186	$186
Phase VI	$4,000	$4,000
Total	**$11,679**	**$39,792**

The City has used a phased approach to implement fiber installation. To consolidate and ease procurement, we recommended expanding the Phases to other ITS Elements. The planned phases are:

Phase I: *COMPLETE*. Fiber Optic cable and conduit on Duke Street, Quaker, King Street, Seminary and North Beauregard.

Phase II: Installation Complete. Fiber Optic cable and conduit on US Route 1, Washington Street, Old Town portion of King Street and segments of Van Dorn and Beauregard.

Phase IIIa: Connect Signals to Phase I Fiber, add CCTV and RWIS, expand the TMC. Design in procurement. 2019-2020.

Phase IIIb: Upgrade ATMS, implement TSP, and begin Adaptive Traffic Signal Control**.** In this Phase the City will upgrade their Signal management systems and begin ATSC. Planned for 2019-2020.

Phase IV: Expand Fiber, ATMS and TSP**.** Connect signals to fiber, and begin new TSP corridor. Planned 2020-2023.

Phase V: Complete Fiber Optic Connections and new corridors; Expand Traffic Management Center, Bike and Ped Detection. 2021-2022.

Phase VI – Further Expand Capabilities and AV Pilot**.** Proposed Autonomous Vehicle shuttle service for Eisenhower Avenue or Potomac Yards. Design-2021; Implement-2023.

Smart Cities. Smart Cities has developed into a world-wide movement that utilizes the advancement of digitization, communications, sensors and data analytics to make improvements to city functions. The basic idea is that smart cities leverage and integrate technology to make people's lives better. While the concept of a smart city started to percolate in the early 2000s along with the Internet boom, planners began to really grasp the concept when places like Masdar City in Abu Dhabi were being planned and built around 2010—a utopian world where renewable energy and "personal rapid transit" pods prevail.

Smart city initiatives are broad and typically encompass a wide range of city functions. Outside of federal seed grants, most of these initiatives include private investments in the form of public-private-partnerships (P3). These partnerships typically allow a private company to use public space for their own research and development efforts, improve their service offerings, or simply provide a form of branding and outreach. If there are willing partners, these types of investments can provide huge returns to a city. We are recommending that the City considers P3's as potential source of funding for of advanced transportation solutions.

Summary. This Master Plan lists near and long-term deployments to continue Alexandria's ongoing ITS efforts and to prepare for future technologies. Many of the near-term deployments – such as Transit Signal Priority and Adaptive Traffic Signal Control - provide a bridge to emerging future technologies. These future technologies include Connected and Autonomous Vehicles and infrastructure for Smart Cities. The Plan consists of VI Phases, culminating in a Pilot of an Autonomous Shuttle in 2023.

The City has funds for many of the ongoing near-term deployments, however an additional $11.7 Million is needed to meet the full six Phases. The projects that comprise this $11.7 Million shortfall improve safety, ease congestion and promote economic development. They are good candidates for Northern Virginia Transportation Authority, Smart Scale funding and CMAQ grants.

This plan relies on our current knowledge of communication, signal control and traffic management technology. It also relies on our knowledge of existing and emerging travel patterns and demographics. As these elements change, so should this Master Plan.

1 Overview

The City of Alexandria is a diverse urban community with a strategic location in the Washington DC area. The City's prime location and metropolitan atmosphere attracts new commercial, retail and residential development. The City has a knowledgeable citizenry and a government that is committed to multimodal transportation and leadership in the use of innovate technology.

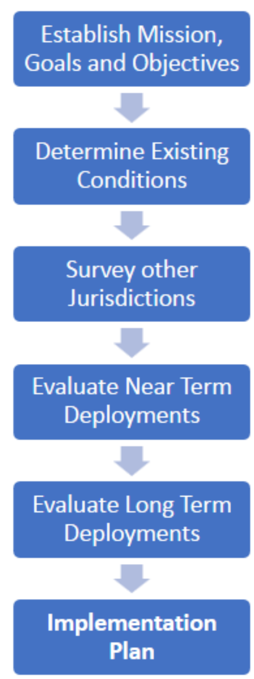
The City of Alexandria currently has an operating Traffic Management Center (TMC), fiber optic connections to signals, and uses many Intelligent Transportation System (ITS) technologies. Although many elements and ITS technologies are in place, the City recognizes an ITS Master Plan is needed to best use the investments it has made, and to guide future efforts.

This ITS Master Plan provides a roadmap for future ITS deployment that is consistent with the City transportation management goals and objectives and leverages currently deployed infrastructure. It includes a list of specific activities and a Systems Engineering Plan. The Master Plan provides a framework to:

- Provide management of all traffic signals within the City's traffic signal system at the TMC;
- Evaluate the City's current TATICS™ Advanced Transportation Management System to determine its suitability and scalability for the City's future needs;
- Upgrade the current traffic signal system to meet the City's future needs;
- Implement Adaptive Signal Control Technologies (ASCT);
- Manage signals and the ASCT;
- Provide centralized control of Portable Changeable Message Signs (PCMS);
- Store, retrieve and share data and conduct trend analysis;
- Plan and manage detours of traffic.

The Master Plan is developed following a traditional planning approach. The approach consists of six general tasks:

1. Determine the Mission and Goals for the Plan. Determine the needs of the key Stakeholders. Follows in Section I.
2. Review the Existing Signal, Communications and CCTV System. Section II.
3. Determine common practices in other communities and VDOT. Section III.
4. Identify and evaluate near term deployments.
5. Identify and evaluate long term deployments.
6. Create the Implementation Plan.



Section 1.1 shows the Mission, Goals and Objectives of ITS and of the ITS Master Plan that was developed in the Stakeholder meeting. Section 1.2 lists specific needs for each Stakeholder.

1.1 Results of Stakeholder Meeting

> **Transportation Vision**
> *The City of Alexandria envisions a transportation system that encourages the use of alternative modes of transportation, reducing dependence on the private automobile. This system will lead to the establishment of transit-oriented, pedestrian friendly village centers, focused on neighborhood preservation and increased community cohesion, forming a more urban, vibrant and sustainable Alexandria. The City will promote a balance between travel efficiency and quality of life, providing Alexandrians with transportation choice, continued economic growth and a healthy environment.*

The Mission, Goals and Stakeholders Needs were developed in two separate meetings. The first, held with City Transportation & Environmental Services (T&ES) and Dash Staff was held on June 19, 2017. The second was held with a broad group of Stakeholders on June 26, 2017.

The Mission and Goals were also informed by the City's Transportation Master Plan. The City's Transportation Master Plan's Vision and guiding principles envisions a significant role for ITS in the City.

Based on the two meetings the following Mission, Goals and Stakeholder Needs were established:

ITS MISSION:

The mission statement provides a summary of the long-term aims of ITS deployment. It establishes what is being done and why it is being done. The mission is as follows:

> *"Serve the transportation needs of the City of Alexandria by improving safety, reliability, and sustainability through the deployment of intelligent transportation systems."*

CITY ITS GOALS:

- Improve traffic safety
- Reduce incident response times
- Improve bicycle and pedestrian opportunity and safety
- Improve transit reliability
- Improve travel time reliability
- Promote seamless multi-modal transportation alternatives to single-occupancy vehicles
- Promote smart cities capabilities
- Allow network and system expansion in an orderly, efficient manner
- Allow future integration of emerging technologies
- Improve joint operations between departments and jurisdictions
- Improve quality and availability of traveler information
- Adopt open standards to allow interconnectivity with VDOT and surrounding jurisdictions.

With regards to the Master Plan itself, the following guidance was provided for developing the Master Plan:

ITS MASTER PLAN MISSION: "Create a roadmap for future ITS deployment that is consistent with the City transportation management goals and objectives while leveraging currently deployed infrastructure."

ITS Master Plan Goals

- Develop an ITS mission and vision statement and prioritize stakeholder needs
- Identify priority ITS Services for City Traffic Department
- Document existing and planned transportation and communication projects in the City
- Identify and prioritize projects for the City and project phasing.
- Develop a concept of operations focused on operations, staffing and maintenance of ITS elements in the City
- Address systems integration to support multijurisdictional coordination with additional City and regional stakeholders
- Ensure consistency with the Regional ITS Architecture.

Basic Plan Requirements

- Operations Center with Conditions Map
- Evaluate existing hardware and software
- Determine new technologies that will lay the framework for future deployments
- Staffing and operational needs and costs
- Pedestrian and bicycle detection
- Support for dispatch from the Operations Center
- Parking Management.

1.2 Stakeholder Needs

1.2.1 1. Transit Providers – DASH, WMATA and Fairfax County Connector

Note: Transit Signal Priority, Automated Vehicle Location and Computer Aided Dispatch are assumed to be integrated into current operations for all operators.

- Bus Operations
  1. Dynamic Scheduling (headway management) for integration of bus operations, rider information and related Transportation System Management (TSM) activities.
  2. Performance measurement of ridership, on-time performance and vehicle loading
  3. Integrated Corridor Management programs for I-395, US1, BRT corridors and George Washington Parkway / Washington Street
  4. Incident, snow and work zone data from each other's TMCs.

- Fare, Inventory Management and other Transit Operations
  1. Fare Payment for On-board, Off-board and regional Partner processes
  2. Inventory and tracking of assets and management of repairs and replacement
  3. CCTV on vehicles and at Metrobus stations for use in enforcement of public safety
  4. GIS layers of asset and routing information
  5. Mobile Maintenance Systems monitoring of vehicle conditions and reduction of in-service breakdowns.

- Customer Communications
    1. Customer Electronic Information Display program
    2. Dynamic electronic displays in rail stations for advertising and customer information
    3. Electronic neighborhood maps and new Public Information Displays in rail stations
    4. Security Call stations as standard at transit terminals
    5. Complaint management and public interface regarding comments about service or facility conditions
    6. Bus route/schedules and real-time status information delivery via Internet/Web portal and mobile apps.

1.2.2 City Traffic – Traffic Management Center.

At the heart of the TMC will be a data Conditions Map and ability to take action from the Map.

- Needs for map:
    1. Incidents (detection, response, manage, close);
    2. Traffic conditions (congestion, average speeds);
    3. Work zones (location, type, duration);
    4. Maintenance and snow removal vehicle locations and status;
    5. Status of traffic signals, detectors, and other ITS infrastructure;
    6. School flashers (schedule and status);
    7. Roadway weather conditions (RWIS);
    8. High water sensors.

- Connections to other Operations Centers
    1. DASH
    2. City 911
    3. City EOC
    4. VDOT Northern Region Operations
    5. WMATA and Fairfax County Connector
    6. Other jurisdictions (i.e. Arlington Co.).

- Other TMC:
    1. Traffic data archives – RITIS plus City streets
    2. Staffing for ongoing daily monitoring, dispatch and maintenance
    3. Staffing incident management
    4. Ability to manage dispatching of Public Works vehicles.

1.2.3 City Traffic – Traffic Signals.

<u>Needs:</u>

- Adaptive Traffic Signal Control
- Enhanced pedestrian detection (short term)
- Improved pedestrian and bike safety using connected vehicle technology (long term)
- Dynamic clearance intervals including variable all-red via use of pedestrian and bike probes

- Prepare for connected vehicles, broadcasting Basic Safety Messages (BSM) including Signal Phasing and Timing (SPaT) and intersection geometry MAP messages via use of DSRC or equivalent cellular technology.
- Transit Signal Priority (TSP)
- Hi-resolution controller data collection (Purdue Coordination Diagrams)
  Performance monitoring and reporting.

1.2.4 City Transportation Planning

<u>Needs</u>:

- Traveler Origin-Destination data
- Mode choice data
- Roadway network performance data by time of day (travel time, travel time reliability, congestion, volume)
- Support of Vision Zero.

1.2.5 City Parking

<u>Needs:</u>

- Parking app for residents and visitors showing availability and pricing
- Automated means to pay – license plate recognition, pay by phone or other technology
- Data to manage curbside and garage parking
- Data to have variable or dynamically price parking
- Ability to enforce residential parking restrictions.

1.2.6 Alexandria IT

<u>Needs:</u>

- Cyber security integration
- Fiber/infrastructure resource sharing, NCR Net access to external agencies
- Common fiber management system
- Network management system.

1.2.7 City First Responders – Alexandria Police, Alexandria Fire, Arlington county Fire, Fairfax County Fire

These agencies have a common set of needs that allow them to coordinate with each other. Fairfax County and Arlington County EMS respond to fires within the City of Alexandria and need to be provided access to City Emergency Management services

<u>Needs:</u>

- Connections and sharing of data from 911 Center and other operations centers
- Connection to other City agencies from police vehicles, municipal wireless type service
- Traveler information outlets for general information and amber alerts
- Access to traffic surveillance CCTV for situational awareness
- Real-time traffic information to aid in dynamic routing.

1.2.8 City 911 Center

Needs:

Sharing of data from Traffic Management Center, including

- Incidents (detection, response, manage, close)
- Traffic condition (congestion, average speeds)
- Work zones (location, type, duration
- Maintenance and snow removal vehicle locations and status
- Status of signals, detectors, and other ITS infrastructure
- School flashers (schedule and status)
- Roadway weather conditions (RWIS)
- High water sensors.

1.2.9 Arlington County

Needs:

- Capability with all systems
- Signal coordination on shared roadways
- Sharing of data from TMC, especially on shared roadways.

1.2.10 VDOT NRO

Needs:

- Two-way sharing of data from TMC / Traffic Management Center especially:
  - Incidents
  - Average speeds on roadways
  - Work zones
  - Maintenance and snow removal vehicle locations
  - Shared roadways and Interstate ramps
  - Parking
  - Flood alerts.
- Evacuation coordination, incident response coordination, and signal timing coordination (especially at border and at ramps).
- Visibility of City Dynamic Message Sign location and messages in real-time.
- Sharing of CCTV Traffic Surveillance
- Participate in the future ICM Decision Support System (DSS) by sharing data and agreeing to execute recommended actions.
- Capability to disseminating SPaT data (thru the Data Portal).
- Established interfaces with VDOT systems and maintain interoperability.

1.2.11 MW COG Transportation Planning Board

Needs:

- Two-way sharing of regional traffic and transit data with Regional Integrated Transportation Information System
- Origin / Destination Data
- Operations Center Connection.

2 Existing ITS Infrastructure

The City of Alexandria has in place many ITS technologies on its transportation network. To meet the City's ITS Goals (page 1-2 and in box below) new initiatives must be superimposed on the existing network of ITS technologies, conventional traffic control systems and streetscapes.

This Chapter will identify the existing ITS deployments and conventional infrastructure. This Chapter will also identify ongoing projects and existing shortfalls.

CITY ITS GOALS:

- Improve traffic safety
- Reduce incident response times
- Improve bicycle and pedestrian opportunity and safety
- Improve transit reliability
- Improve travel time reliability
- Promote seamless multi-modal transportation alternatives to single-occupancy vehicles
- Promote smart cities capabilities
- Allow network and system expansion in an orderly, efficient manner
- Allow future integration of emerging technologies
- Improve joint operations between departments and jurisdictions
- Improve quality and availability of traveler information
- Adopt open standards to allow interconnectivity with VDOT and surrounding jurisdictions

2.1 Ongoing Projects

The City's ITS Infrastructure is in the process of being upgraded. Minor improvements are implemented constantly by City Staff as they use the system. In addition, several significant projects are recently completed, underway, or funded:

- Phase I Fiber Optic Installation – This project added fiber optic communications on King Street (RT 7), Duke Street a portion of Quaker Lane and Seminary Road. This project did not connect controllers to this fiber; these connections will be performed in Phase III. See Exhibit 2.1 for a map of Phases.
- Phase II Fiber Optic Installation – This ongoing project is to install conduit with Fiber Optics. Construction began on May 2016 and is scheduled to be completed May 2018.
- Phase III Fiber Optic Installation, and Signal Connection. This is a federally funded project. Design will begin in early 2018 with construction complete in late 2018. This phase will also connect signals to existing fiber on portions of Duke, Seminary, Quaker Lane and King Street. Exhibit 2.1.
- Phase IV Fiber Optic Installation, and Signal Connection. This project scored well in the 2015 Virginia Smart Scale prioritization process and is expected to receive District Grant Funds (DGF). Design will occur in 2018 and construction is expected to start in late 2019 or 2020.
- Transit Signal Priority (TSP) Design – This study is designing TSP for portions of two corridors: Duke Street, and US Route 1. The study also evaluated and recommended new Advanced Transportation Controllers (ATC) as part of the TSP deployment for these corridors. The design was completed in 2017 and will be implemented on these corridors in 2018. Already completed projects include TSP along Van Dorn St. and Beauregard St. for WMATA buses using Siemens TACTICS and TSP enabled controller firmware.

- Adaptive Signal Control for Multiple Corridors. This project also scored well in the 2015 Virginia Smart Scale prioritization process and is expected to receive District Grant Funds (DGF). Design is expected to begin in 2018 and implementation will be phased with completion by 2023.

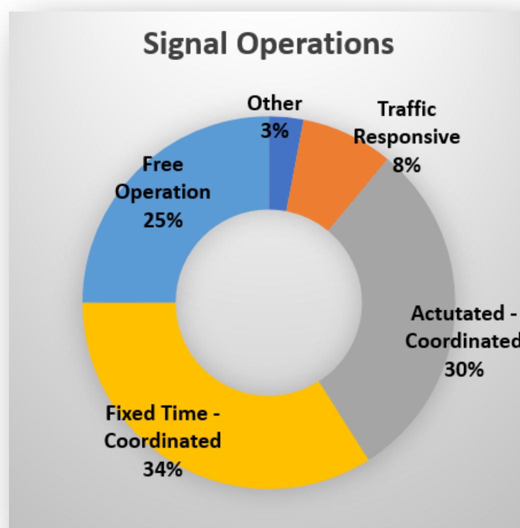
2.2 Traffic Signal Systems

The City of Alexandria owns, operates and maintains all traffic control signals within its boundaries that are not part of the Interstate Highway System. Within the City's boundaries, there are five signals located at Interstate ramp terminals that are owned and operated by the Virginia Department of Transportation (VDOT). There are 254 traffic signals system wide, with 197 under central monitoring and control from the Traffic Management Center (TMC). The City uses the Siemens TACTICS Central Advanced Transportation Management System (ATMS) to control and manage the signals under centralized control.

Communication between the TMC and the traffic signals is via fiber and copper. Fiber optics lines form the backbone of the system. And, except for last mile provisioning, the City is transitioning from the older copper lines to newer fiber lines which offer significantly more capacity and speed. With implementation of Phase II, III and IV, all the major corridors will be connected with fiber communications.

Advanced Transportation Management System (ATMS) - The City currently controls and manages its traffic signals using Version 3.2.3 of the Siemens TACTICS ATMS. There is an ongoing Transit Signal Priority project which will involves signals located along the Duke Street Corridor and Rt 1. This project will upgrade ATC traffic signal controllers and evaluate ATMS systems.

The TSP project is scheduled for completion in 2018. Once the project is complete, both systems will be fully operational and operate side-by-side but independent of each other. The City will then begin a transition to the ATMS solution that best fits its needs.



Coordinated fixed time and actuated coordinated signals account for 64% of the signals. Signals with free operations are generally isolated or on lower volume residential streets.

The existing TACTICS ATMS supports the following traffic signal modes of operation:

- Time of day
- Time-based
- Manual
- Flash
- Preemptive/priority
- Traffic responsive

EXHIBIT 2.1 – Fiber Installation Plan

Traffic signals operating under the TACTICS system are centrally coordinated, but locally run. This increases system robustness by allowing traffic signals which have lost communications to operate with a local copy of the current traffic signal timing plan.

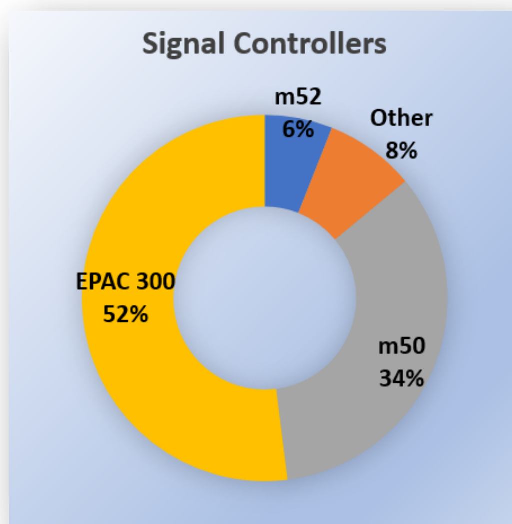
Computer Network Topology and Security – The City has implemented several strategies to secure and safeguard its traffic signal network. The City uses VLANs to segregate its network and limit access to various segments of the network. The City uses fixed IP addresses instead of DHCP address assignment so unauthorized devices connected to the network do not automatically get assigned an address and access to the network. Each traffic signal cabinet has a physical lock to limit entry. There currently is no wireless access or Bluetooth access to the network. As accessibility is given greater consideration, additional security measures will need to be put in place.

Controller Cabinets - The City uses a combination of NEMA TS-1 and NEMA TS-2 controller cabinets. Of the 254 traffic signals in its inventory, 144 use a NEMA TS-2 Type 2 Cabinet. The remaining signals use the NEMA TS-1 controller cabinets.

NEMA TS-1 cabinets are the older style cabinets and many have been replaced by the NEMA TS-2 standard. The Advance Transportation Controller (ATC) cabinets are desirable, and even necessary, to keep up with the additional inputs and outputs being handled by the controllers and more advance traffic signal control strategies.

Table 2.1 - Cabinet Channels

	Detector Channels	Output Channels
NEMA TS-1	24	16
NEMA TS-2	64	16
ATC	120	32



The City is examining the use of ATC cabinets and controllers in its traffic signal system. The ATC cabinets offer additional benefits which include less space per installation, high density (HD) components and low voltage operation. HD components reduce power consumption significantly. Low voltage operation increases safety for signal personnel.

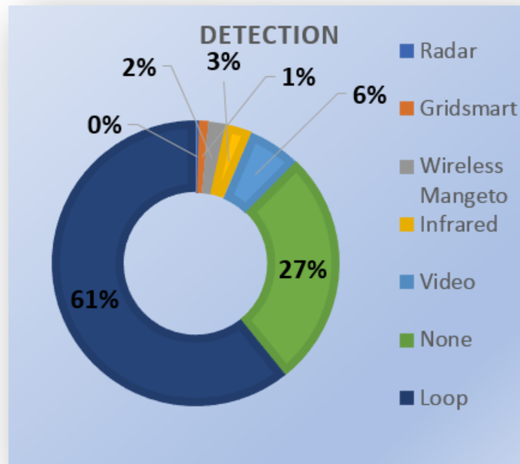
Controllers – Most of the City's controllers are from Siemens. The predominant controller in use is the EPAC 300 Controller. The term EPAC is an abbreviation for Eight Phase Actuated Controller. These controllers, once considered a workhorse of the industry, are being largely replaced by newer and more powerful models.

The capabilities of the equipment in the City's inventory vary significantly. The older EPAC machines cannot collect high resolution data which is becoming increasingly common for monitoring and reporting signal performance measures. They also lack the capability for future Connected Vehicles /

Autonomous Vehicles (CV/AV) applications. Some of the more recent m-series controllers may have their capabilities extended through firmware upgrades.

Firmware - The City currently uses over 24 different firmware versions on its traffic signals. These installations range from Versions 3.13f to 3.55 of the Siemens firmware. The most common firmware installations are as follows.

Table 2.2 - Firmware Installs		
	Firmware Version	Number of Installs
1	3.34g	66
2	3.30c	44
3	3.32d	28
4	3.55	14
5	3.32f	11



Detection - Approximately 73% of the City traffic signals have vehicle detection deployed. The City uses a variety of vehicle detection technologies for its traffic signals. The primary method of vehicle detection for the City is loop detection, with 61% of signals. Video is the next highest, with 6%. Other technologies are represented in small numbers as shown in the chart.

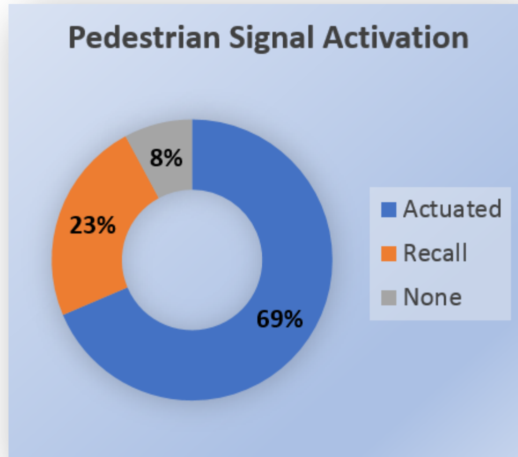
Uninterruptible Power Supply (UPS) – The City's Traffic Management Center has a UPS System and a Backup Generator to keep the system running during a power outage There are 11 deployments of the UPS Stealth System which is a dry pack battery technology. The City is also piloting a hydrogen fuel cell backup system at one of its intersections. At this time, the system has just been made operational and the City is learning from its experience with this system.

Maintaining battery backup requires regular maintenance, and batteries will operate a signal for less than four hours. As such, battery backup is prudent at key intersections where temporary outages will have a significant impact. Recent power outages due to weather have been for much longer, however most outages are for short periods of time[3].

Bike and Pedestrian Signals. The addition of pedestrian signals and pedestrian phases to existing traffic signals has been a priority for the City. Actuation is provided at 65% of the signalized intersections. Of the remaining signalized intersections, 23% operate on recall mode which automatically provides a pedestrian phase without the need for pedestrian activation.

[3] Howard County, Maryland reported experience is that 80% of outages last less than 3 minutes.

Recall mode is most common in the Old Town area where more pedestrians are present and where more crossing opportunities are required.



The City's actuated pedestrian signals use pushbuttons or accessible pedestrian signals (APS). The City does not use any active systems that detect the presence of pedestrians to actuate the pedestrian signal. The stakeholder group identified this technology as one of the areas of need for the City.

The City has two HAWK (High-intensity Activated cross WalK) pedestrian signals located along the Van Dorn Street and Eisenhower Avenue corridors. These signals provide crossing opportunities where these opportunities would otherwise not exist. HAWK signals are relatively new having been adopted in the most recent Manual on Uniform Traffic Control Devices (MUTCD). They offer reduced disruption to traffic flow during a typical signal cycle.

Exhibit 2.2 shows installations of City's pedestrian detection across the City. The map also shows locations of traffic signals with no associated pedestrian traffic signals. There are 19 intersections without pedestrian signals.

Shortfalls and Challenges.

Advanced Transportation Management System (ATMS). The City lacks a full-featured ATMS with the capabilities and functionality as discussed in Section 4.4. The Siemens TACTICS traffic signal system provides the City with basic centralized traffic signal management capability, but is limited in its ability to support the additional transportation management services.

Computer Network Topology and Security. As additional services and applications are integrated into the current ITS network and as the reach of this network expands to other City and regional facilities, security will become a more important consideration. Security related network issues and the need for a Communications Implementation Plan are further discussed in Section 4.9.

Controller Cabinets. Nearly half (110 of 254) of the cabinets are the older, NEMA TS-1 type cabinets. These older cabinets will make implementation of advanced systems more difficult, if not infeasible. In the near term only the TS-1 cabinets located on coordinated corridors need to be upgrade. With many of the proposed Connected Vehicle/Autonomous Vehicle technologies all signals will host new systems and the older cabinets will be limiting.

Controllers. With the addition of fiber optics communications to nearly every significant corridor the controllers will quickly become the limiting element in the system. The older EPAC 300 and even the m-class are not suitable to support the more advanced signal control functions such as ATSC, TSP, and CAV.

Detection. The City's current detection serves its current needs and does not preclude upgrading, should superior technology become available. Advantages and disadvantages to replacing the City's loops and other detection options is discussed in Section 4.5 Detector Options.

Uninterruptible Power Supply (UPS. The Traffic Management Center (TMC) has backup power, and 11 traffic signals are served by battery UPS. The critical signals also have power adapters for connecting field deployed generators.

Bike and Pedestrian Signals. Future intelligent systems that account for bikes and pedestrians will be as limited as the communications network, cabinets and controllers. The City has a good start in implementing bike and pedestrian technologies with so many pedestrian signals and favorable intersection geometry over much of the City.

Active pedestrian detection in which the signal automatically detects the presence of a pedestrian is not currently being used. This type of technology will complement Connected Vehicle technologies by adding the detection of pedestrians and bikes.

Mobile Device Tracking: The tracking of mobile devices, such as smart phones and tablets using WiFi or Bluetooth signals provides an opportunity to supplement traditional single point detection. With the development of the appropriate algorithms the system will be able to discern/track the movements of buses, pedestrian, bicycles and cars through the network and use that knowledge to better harmonize traffic signal operations with multi-modal uses.

Data Harvesting: Data from system detectors and mobile device tracking can be compiled and stored to provide historical trends and future predictions. This data can be used for planning and forecasting.

2.3 CCTV Camera Surveillance.

The City operates 11 traffic surveillance CCTV cameras over a combination of fiber optic and twisted wire pair cable, and is in the process of installing another 10 CCTV cameras on new fiber cable as part of the Phase II Fiber Optic Installation project. Cameras are becoming a commodity item with universal support for IP-based standardized video compression (H.264) and standard control/status interface (ONVIF, NTCIP) providing universal interchangeability. The city uses Bosch cameras and a Bosch Video Management System (VMS) to monitor and control cameras at the TMC.

Exhibit 2.3 shows the location of CCTV cameras.

CCTV Shortfalls / Opportunities: Visibility of all the City's arterials will aid decision makers with real time information. The 11 CCTVs do not provide comprehensive coverage. Video is currently only accessible at the City TMC and is not integrated with VDOT's 511 system or RITIS.

Exhibit 2.2 – Signals without Communications / Signals without Pedestrian Signals

Exhibit 2.3 - CCTV Location Map

2.4 City Traffic Management Center TMC

The Traffic Engineering Division operates the City's Traffic Management Center (TMC). Critical events such as snow removal, weather related operations and special events as well as day-to-day operations are managed from the center.

View of Traffic Engineering Division TMC

The Traffic Engineering Division is co-located with the TMC at 2900 Business Center Drive. This facility is relatively new and has space and building infrastructure to manage traffic during normal and emergency operations.

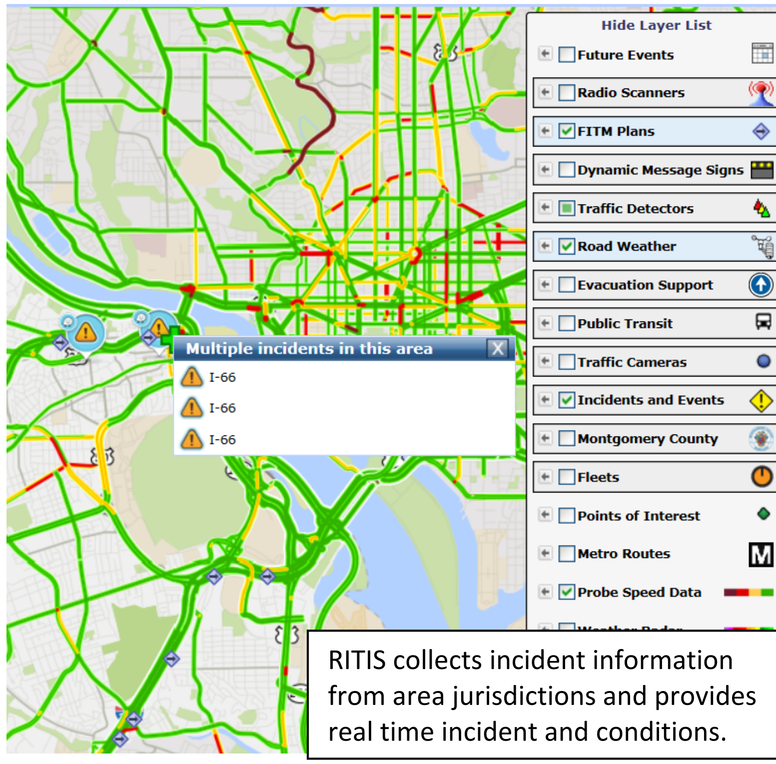
Signal Control. The TMC controls the City signals via TACTICS Central version 3.2.3, with an upgrade pending. This system is adequate to modify signal timing and phasing, troubleshoot, and monitor signal operations. The City's chief complaint is that support does not meet expectations.

TACTICS is modular and scalable. It will function with new controllers and many potential Adaptive Signal Control systems being considered. TACTICS can meet the needs of additional signals connected via fiber optics.

Emergency Operations. During snow events or other emergencies, the TMC serves as an operations center providing instructions to snow plows and maintenance teams and providing information to DASH, fire and police. The TMC, via TACTICS, will also modify signal timing and phasing in response to the situation if necessary. The Director of Transportation and Environmental Services will visit the TMC, although the Director operates primarily from the Emergency Operations Center (EOC) during emergency and other special operations.

The primary TMC area consists of 5 monitor stations and 8 temporary stations. There is adequate room in the Transportation Division offices to host a large number of planners, managers, liaison personnel and other staff that could be expected during an emergency. The HVAC is expected to be adequate, and there is room for cots and two showers to accommodate continuous operations. The TMC has a UPS which acts as a bridge to a natural gas generator.

Primary communications with other operations centers is via phone, text and email. VDOT's Lane Closure Advisory Management System (LCAMS), 511 and the Regional Integrated Transportation Information System (RITIS) show incident locations, work zones, evacuation routes and stations and other transportation related data. Video information from VDOT and other jurisdictions is available through 511 and other means via the internet.



RITIS collects incident information from area jurisdictions and provides real time incident and conditions.

<u>Current Staffing</u>. The TMC is manned part time by Traffic Engineering Division personnel. Including managers, there are 5 traffic section staff. Most weekdays staff will watch over conditions and monitor news reports while performing other work. In this manner the TMC is active 5 days a week for 12 hours. During emergencies other city employees are brought in to help staff the TMC on two 12 hour shifts providing 24 hour coverage.

TMC Shortfalls and Opportunities. The framework for a secure and capable Traffic Management Center is present. With the addition of Phase II, III and IV fiber the TMC will have a high capacity and secure communication backbone to the signals and throughout the City.

The TMC needs a central map that can show electronic overlays of the most critical information. CCTV feeds and roadway status applications such as 511 and RITIS or even Google Maps currently provide the status of area conditions. However, there is no consolidated conditions map that incorporates relevant spatial data such as roadway conditions, AVL data, work zones, incidents, and weather into a multilayered conditions map.

Another future requirement of the TMC is the ability to electronically exchange information with neighboring jurisdictions, publish traveler information, and remotely manage systems outside of the TMC. The TMC will also be more effective if elements can be monitored and controlled remotely.

Staffing of the TMC is not adequate for normal day-to-day operation. Staffing alternatives are discussed in Section 4.10.

2.5 Communications System

The City has a combination of copper and fiber optic cable installed in conduit infrastructure connecting 197 of the 254 traffic signal cabinets. After Phase IV 152 signals will be connected with fiber optic cable and 49 will be still be connected via cooper.

Table 2.3 - Signal Communications Fiber / Copper

	Number
Fiber Optics	152
Copper – Duke Street	9
Copper other	40
None	53
Total	254

The connected signals and other field ITS devices connect back to the Traffic Management Center (TMC) at 2900 Business Center Dr. There is also a significant amount of the copper infrastructure, particularly in Old Town, installed in Verizon manholes and duct banks. The City's agreement with C&P Telephone, Verizon's predecessor, expired years ago and while the existing cables are grandfathered, the City cannot utilize these duct banks for new installations.

The copper twisted wire pair cable consists of a combination of 25, and 12 pair 19AWG segments emanating in a hub-spoke design from City Hall at 300 King Street out to the field devices. The communication circuits are back hauled to the TMC using two 25 pair cables. These cables are primarily used to interconnect the traffic signal controllers with the TACTICS central traffic control software using half-duplex, 1200 baud, multi-drop analog modems. Very-high-bit-rate digital subscriber line (*VDSL*) communications allow Ethernet/IP communications to TACTICS using copper cable along Duke street. VDSL also provides high speed connectivity to the controllers, detectors and other auxiliary equipment. There are other VDSL circuits along this corridor that provide last mile connections to the fiber to support CCTV video.

The existing copper communications are located in City and telephone conduit. Exhibit 2.4 show the location of each.

The fiber cable originating from the TMC will all be single mode. Current fiber cable is used mainly to support traffic surveillance CCTV communications, but the City plans to also use this resource to interconnect traffic signal controllers and other ITS devices. The City is also evaluating passive optical networking (PON) technology in an effort to determine the optimal communications techniques moving forward. The PON is currently installed at non-CCTV locations as part of a test bed for comparative study to the more popular active fiber/Ethernet solution. The PON solution holds promise as a lower cost alternative to the more common Ethernet options.

Except for one segment of Duke Street, fiber will be located on every major corridor in the City at the conclusion of Phase IV. The 2.0 mile of Duke Street copper is newer and higher capacity, as such has not been a priority to replace.

EXHIBIT 2.4 COPPER ASSETS

Shortfalls

- Aging Copper Cable Infrastructure – much of the copper cabling is nearing the end of its useful life and will need replacing or upgrade in the near future.
- System Redundancy – all of the cable and communication links terminate at the TMC providing only limited route diversity redundancy and TMC link remains a single point failure.
- Network Management – limited remote network monitoring and management capabilities over fiber and VDSL links. The current analog modems are non-intelligent devices with no management capabilities.
- Standalone Cabinets – not all traffic signal cabinets are interconnected with communications limiting central TMC management capabilities. 53 traffic signal cabinets are not supported by any communications interconnect. The location of these signals is shown in Exhibit 2.2.
- TMC Networking – there is limited wide area networking capability to share information outside of the TMC environment. The City is constructing a tie-in with the National Capital Region Network (NCRNet) via Arlington.
- Missing Fiber on three arterials – Eisenhower Avenue, portions of Duke Street and Mount Vernon.

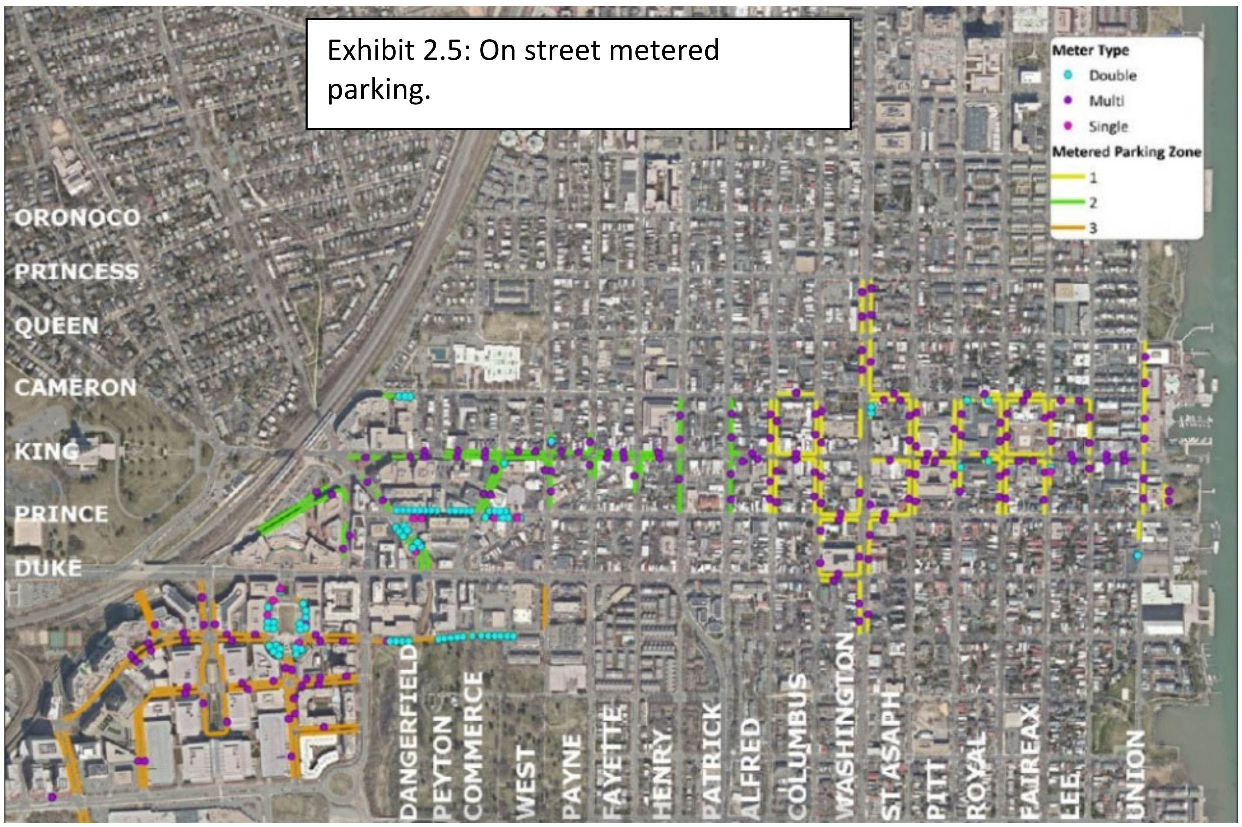
Opportunities

- A **Phase V Fiber** installation. Eisenhower Avenue and Duke Street "missing links". Mount Vernon, provides direct north-south connectivity, however it is a lower volume minor arterial through a residential area.
- Reconfigure copper twisted-wire cable – copper cable may be reconfigured for "last-mile" connections to the fiber backbone and using xDSL technology to bring broadband communications to all traffic signal cabinets. This may be a cost-effective reuse of existing infrastructure to provide similar broadband service to a majority of the cabinets
- Route Diversity – with broadband type communications it is possible to take advantage of the existing cabling routes to configure diverse paths by which communications are supported to each cabinet to improve overall network reliability. Additional routing to the TMC or possibly to an alternate backup center should be investigated.
- Resource Sharing – the City IT department has similar broadband communication needs throughout the City with common resources such as conduit, cabling, and networks.
- Wireless Gap Filling – where cable infrastructure currently does not exist the City may use point-to-point private wireless or possibly cellular to connect standalone cabinets.
- Security – as the network expands and more functions supported security will become an increasing concern. Since the broadband network elements are just now being deployed it will be easier to design in appropriate security measures consistent with City policy and industry best practices.
- Network Management – active centralized monitoring and management of communications infrastructure allows for a more proactive response to impairments and degraded service to avoid major outages. It also allows for centralized configuration management of field devices.

- Asset Management – documentation of cable routes, configuration and condition assessment is critical to managing existing infrastructure. A GIS-based tool for managing communication physical assets is needed.

2.6 City Parking

The City maintains the City Town Hall Parking Garage with three levels and metered on-street parking in the Old Town and Patent and Trademark areas. In addition, there are 16 commercial parking garages with 4,300 spaces and or 10 hotels with 2,300 spaces (source: Parking Standards for New Development Projects Study Phase 2 –Commercial Uses).



The City's on street, metered parking has electronic payment options including pay by phone.

The City is in the process of studying parking and developing policy. Typical of these efforts is the Old Town Area Parking Study (OTAPS). The OTAPS Work Group made the following goals for improving parking management in their study area:

1. Encourage short-term visitors to park in metered areas rather than residential blocks;
2. Encourage long-term visitors to use transit and park in off-street garages and surface lots;
3. Preserve parking on residential blocks for residents and guests;
4. Encourage compliance at meters and in residential parking districts.

The OTAPS Work Group also made several recommendations including: *"Provide and promote digital wayfinding with parking garage information through mobile applications and websites, and maintain a current City parking map".*

Making parking easier and more accessible is, generally, counter to the City's objectives to encourage transit, biking and walking. However, smart parking will allow parking to be managed and focused to support the City's transportation objectives.

Parking Shortfalls / Opportunities: The metered on-street parking could be monitored for payment status. City parking meters currently have electronic payment and pay-by-phone capabilities. There are apps that allow visibility of which spaces are in a paid for status. While this is only a surrogate measure, it does provide a relatively good indicator of parking availability. Smart on-street lights with integrated detection and wireless communications is one solution being used to sense curbside occupancy. This may be an option in Old Town where the City owns the street light infrastructure.

The City parking garage detection entering and leaving provide an easy method to estimate availability. Additional detection for the reserve spaces and handicap spaces is necessary to provide a precise availability.

2.7 DASH Transit Technologies

The City Transit Company (DASH) operates a bus transit Computer Aided Dispatch and Automatic Vehicle Location (CAD/AVL) system provided by Clever Devices for all its fixed route and Old Town trolley revenue vehicles. Communications is via T-Mobile 4G cellular using a virtual private network (VPN) connection over the public Internet to communicate with CAD/AVL servers in the City.

Most of the vehicles in the fleet are equipped with 7-8 onboard cameras with ability to provide live video streams for dispatchers, supervisors and other support staff.

In cooperation with the City, DASH is currently planning a limited unconditional TSP deployment (6 intersections) on the Duke Street corridor to be installed early spring 2018. Possible integration with the CAD/AVL for conditional priority based on passenger load or schedule adherence is not planned. TSP equipment is still being finalized but will most likely be different from what has been installed to support WMATA fleet.

DASH supports an external GTFS (general transit feed specification) feed to provide scheduled arrival time information available to third parties through a public portal and also through its website (https://tracker.dashbus.com/bustime/home.jsp). DASH does not currently support a real-time status feed.

DASH is also installing a series of 5-8 large digital screens to display real-time information (RTI) at several locations throughout the City. The first sign was installed in the City Hall lobby in late 2017. Other locations will be at the Mark Center, King Street Metro, NSF Building, and Southern Towers. DASH is also in discussions with WMATA to install the smaller LED ribbon boards with RTI in 10-15 bus shelters, and also has a small pilot with another company (CHK America) to test at-stop RTI displays at a pair of stops on King Street.

2.8 Roadway Weather Information System (RWIS)

The City has identified 11 high priority locations for Roadway Weather Information System locations. RWIS consists of meteorological and pavement sensors to determine the presence of flooding and the presence of ice and snow. The sensors can also predict where ice may be ready to form. They inform the TMC of where salt, snow removal equipment, warnings, or road closures should be deployed.

RWIS is planned for the following locations. These locations are shown in Figure 2.4.

1. Van Dorn Street bridge over the railroad tracks just north of Eisenhower Avenue
2. Duke Street and S Walker Street
3. Seminary Road and Mark Center Drive
4. N. Quaker Lane, north of Duke Street
5. King Street bridge over I-395 just east of 30th Street
6. Telegraph Road bridge over Duke Street
7. Jeff Davis Highway and E Glebe Road
8. Jeff Davis Highway bridge on Monroe Avenue just north of Slater’s Lane
9. Duke Street and N Henry Street
10. Washington Street and Church Street

Shortfalls and Opportunities. The system as planned does cover most of the City roadway overpasses. This information, taken in conjunction with other roadway information will allow the TMC to make decisions as to where to deploy equipment, place warnings or detour traffic.

2.9 Other Electronic Information Devices – Flashing Beacons, Radar Signs and School Zone Beacons.

The City controls a wide range of electronic devices that provide information to motorists, to the TMC or to both. These devices consist of:

- High Intensity Beacon (HIB) Pedestrian Flashers – 14
- School Zone Flashing Beacon – 45
- Rectangular Rapid Flash (RRF) Beacons – 32
- Radar Signs – 14
- Flood Monitors – 2
- Weather Stations - 10

The Stakeholders did not express a need to expand these types of devices soon. They did discuss the need to be able to take advantage of future roadside safety and informational electronic devices.

Exhibit 2.5, Comprehensive Equipment Map, shows the location of existing devices.

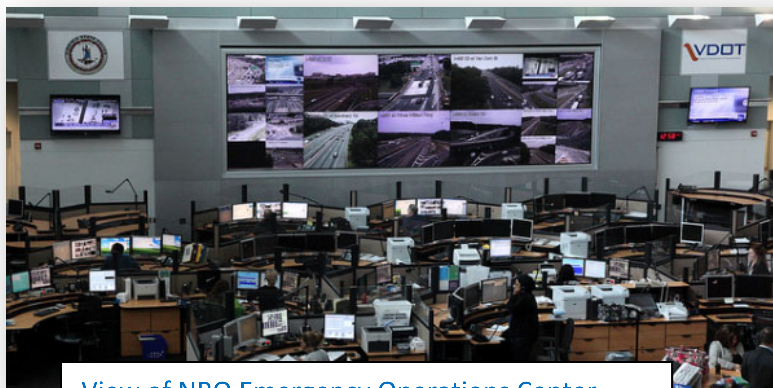
Exhibit 2.6 - Comprehensive Equipment Map

3 Current Practices in Other Jurisdictions

States, municipalities and even the Federal Governments are all grappling with how to best implement ITS and prepare for Connected and Autonomous Vehicles (CAV). At the 2018 Transportation Research Board Annual meeting 86 sessions focused on transformational technologies.

To inform the City of Alexandria ITS plan neighboring jurisdictions were surveyed. Sessions were held with the Virginia Department of Transportation Northern Region Operations (VDOT NRO), and Arlington County. In addition, a telephonic interview was held with Montgomery County and a survey was done of ITS Master Plans performed by similar size Cities.

3.1 VDOT Northern Region Operations (NRO)



View of NRO Emergency Operations Center

VDOT's Northern Region Operations (NRO) TMC, housed in the McConnell Public Safety Center in Fairfax County, is a large and sophisticated operation that encompasses traffic operations for Virginia's most populous area. NRO encompasses four counties, a total of 23 separate jurisdictions with a total population over 2.5 million. Despite the order of magnitude difference, the NRO performs similar arterial management, uses many of the same tools, and faces many of the same challenges as the City.

Like the City of Alexandria, VDOT NRO has many of its 1,400 signals connected to a central signal operations center, and is making investments to bring all signals on line. They currently manage the arterials using 8 time-of-day scheduled preset timing plans. Although VDOT has full time staff and consultant support, the sheer volume of corridors and signals dictates that much of staff effort is devoted to system maintenance and not towards system optimization.

The McConnell Public Safety Center includes State and County Police, fire and rescue, other state agencies and posts for liaisons from the 23 jurisdictions. This complex is tested during weather and other events and is designed for a large or national emergency.

Transit Signal Priority (TSP)is not being actively pursued by VDOT NRO. NRO supports transit in their operations similar to other jurisdictions in their area of operations; however, unlike the City, they are not a transit operator. VDOT recently selected a new state-wide Advanced Transportation Controller (ATC) and firmware standard, and is now in the process of developing an RFP for statewide selection of a standard traffic signal system.

<u>Lessons for Alexandria</u>:

- Colocated Operations: The public safety complex, where all transportation related agencies are co-located, is a concept that should be duplicated. The challenges of maintaining traffic flow through signalized corridors are the same and techniques and procedures should be shared as much as possible.
- Infrastructure light Posture: Let the private sector fill more of the role of traffic data collection and traveler information dissemination, and reduces maintenance demands. With advances in crowd sourced data, vehicle probe data, and traveler information applications VDOT is focusing resources on capabilities the public sector is uniquely positioned to provide.
- VDOT SmarterRoads.org Data Portal: making regional transportation freely available to the public to encourage private sector application development. This includes publishing of CAV data as well.
- VDOT CAV initiatives including the USDOT Pooled Fund Study and the Virginia Connected Corridors (VCC) Initiative have yielded significant lessons learned and positioned Virginia to accelerate CAV deployment (see Section 5). The City should work closely with the VDOT to coordinate deployment of these technologies.
- VDOT ATC and Central Signal System: VDOT recently completed specification and procurement of a state-wide ATC standard and will soon be advertising for a state-wide central signal system. The City may leverage work already completed, and if it meets the City's requirements, may also purchase these systems from the state-wide contract.

3.2 Arlington County

Arlington County is only slightly larger than the City of Alexandria in size and population and has many similarities. They both have a mix of land uses, a central location in the Washington DC area and both have major commuter interstates and primary routes that run through them. Arlington County also manages a similar number of signals; there are 295 signals in Arlington County and 256 in Alexandria.

In Arlington County, the penetration of ITS into transportation operations is similar to the City of Alexandria. Arlington County is implementing fiber communications to most of their signals, are able to control nearly all signals from a Traffic Management Center, and operate a range of monitoring and communication devices on their roadways.

Although the two jurisdictions are in a similar place implementing ITS technologies, there are noteworthy differences. A summary of similarities and differences are in Table 3.1 on the following page.

Arlington County has invested more heavily into ancillary roadway devices. The County has invested in Permanent Count Stations (35), Variable Message Signs (7), and speed indicator signs (23).

The Variable Message Signs are used on major arterials and have the purpose to inform motorists of events, general traffic conditions and metro status. The speed indicator signs are used as traffic calming devices primarily in residential neighborhoods.

Arlington County has installed over 180 CCTV Cameras. On some corridors this provides very detailed visibility and redundancy. Arlington staff believe the large number provides sufficient benefit to warrant the additional maintenance.

The County has Transit Signal Priority (TSP) installed along key corridors and bus routes for Arlington Transit and Metrobus. They also support the WMATA regional TSP program. Although the County did operate an Adaptive Traffic Signal Control system in the past, it has since been decommissioned and there are currently no plans to deploy any other systems. Signal optimization is performed in-house about every 3 years using interns. They feel this is more cost effective.

The County is beginning to install bike lane detectors. The intent of these detectors is to improve safety and extend minimum green times to provide bikes more time to cross. The County is investigating Safe Walk and infrared detection for pedestrians. Infrared detection is in use at Glebe Road / Mount Vernon mid-block crossing.

Variable Message Sign (VMS) on US 29.

The County has invested in Smart Streetlights and is able to monitor and control illumination remotely to about 8,000 of the 9,000 County owned streetlights.

To prepare for Connected and Autonomous Vehicles (CAV) the County is upgrading their traffic signal control hardware to the latest Intelight Advanced Transportation controller (ATC), upgrading traffic signal cabinet hardware to latest NEMA TS2 standards, and adding uninterruptable power systems (UPS) to critical intersections. Although the County DOT and IT departments run separate conduit and fiber cables, the IT department is responsible for maintaining both resources. The drop cables from traffic signal cabinet to the backbone and everything in the signal cabinet remains the responsibility of the DOT. The IT department maintains all head end networking equipment

<u>Lessons for Alexandria</u>:

- Enable regional video and data sharing: Especially useful to coordinate operations and manage incidents crossing jurisdictional boundaries. Use NCRNet to share this information throughout the region.
- Develop MOU or equivalent agreement with IT for fiber and network management.
- Include UPS at critical intersections and considering adding as part of any new cabinet standard.

Table 3-1 compares key features of Arlington County and the City of Alexandria.

Table 3-1: Comparison of Arlington County and City of Alexandria ITS Investments and Planning

Item	Arlington County	City of Alexandria
Centralized Control of Signals	Most of 295 Signals	199 of 256 Signals.
Fiber Communications on major corridors and traffic signals	Three Phase Implementation Plan, all traffic signals included.	Four Phase Implementation Plan, nearly all traffic signals to be included.
Transit Signal Priority	Not Planned	In progress for three corridors
Adaptive Traffic Signal Control	Not Planned	In progress for major corridors
Traffic Management Center (TMC)	Monitor and make traffic signal timing and phasing adjustments. Two locations: City Hall and shop location.	Monitor and make traffic signal timing and phasing adjustments. One location – Traffic Operations area.
CCTV Cameras	182 Cameras	40 Planned, additional in evaluation.
Variable Message Signs	7 implemented	In evaluation
Roadway Weather Information Station (RWIS)	None	6 in place, more planned
Bike Lane Detectors	A few in place	In evaluation
Passive pedestrian detection	Infrared in test	None in test, In evaluation
Parking Management System	None planned other than Smart Meters	None planned other than Smart Meters
Street Light Management	Centralized visibility and control	Not planned
TMC Staffing	No dedicated operators, Office personnel double in emergencies. 5 personnel.	No dedicated operators, Office personnel double in emergencies. 4 personnel.
Signal Shop Staffing	8 Technicians	

3.3 Montgomery County, Maryland

Montgomery County, Maryland is several times larger than Alexandria, but is a Washington DC neighbor with similar transportation issues. As a larger operation in an equally affluent jurisdiction they have had more opportunities to invest in ITS technology. In this respect they provide guidance for future deployments.

The penetration of ITS into transportation operations is similar to the City of Alexandria. Montgomery County has an extensive fiber communications network connecting hub buildings, facilities and the TMC. The fiber also extends to field nodes where the cable transitions to copper signal interconnect cable for "last mile" DSL connection e to each traffic signal cabinet. Traffic signals operate locally with a central override that is managed from their TMC. The County is currently evaluating various Adaptive Traffic Signal Control (ATSC) systems as part of pilot deployment. They are also preparing to collect Signal Phase and Timing (SPaT) data from signal controllers and be able to publish this data to private entities offering cellular-based V2I CV capabilities. The County is also preparing to deploy DSRC-based V2I CV capabilities in the near future in support of the USDOT SPaT challenge.

The County RideOn bus transit service dispatch is collocated with TMC providing active transportation management collaborative opportunities.
Lessons for Alexandria:

- Establish broadband communications to each traffic signal cabinet as a foundational element to support all future ITS and CAV applications. An implementation plan should be developed to guide the detailed design and phased deployment, while working through overall management and support responsibilities
- Shifting from a hands-on and interactive mode of managing traffic signal operations in response to events and incidents to one that automatically adapts to changes in real-time demand using tools such as ATSC and, in the future, one that learns and is able to predict these changes using technologies such as artificial intelligence
- Develop data collection and reporting capabilities that can be used to monitor key performance measures to support data-driven decision making
- Recognize that these capabilities require a sustainable funding stream for ongoing systems operations and maintenance.

A summary of the County's approach to ITS investments is in Table 3.2.

Table 3.2 Summary of ITS Investments, Montgomery County, MD	
Central Systems	Siemens custom ATMS, EM7 Network Management
Number of Signals	850 (~1 per 1,200 population based on 1.04M 2014 census)
Traffic Signal Operations	Local TBC control with central override for incidents or events, highly responsive central operations, investigating adaptive control
Transit Operations	Ride On County Bus dispatch operations co-located with traffic in TMC. GTT Opticom transit signal priority (TSP) with 2.4G V-I communications along MD355 (US29 future)
Field Cabinet Configuration	NEMA TS1/2 cabinets, Econolite ASC/3 controller, some with UPS
Vehicle Detection	Mostly video (Autoscope and Gridsmart) and inductive loop semi-actuated; some Sensys magnetometer, FLIR IR, and SmartMicro under evaluation
Pedestrian Detection	Typically semi-actuated pushbutton, Polara APS
Bike Detection	A few IR camera installations under evaluation
Backbone Communications	Fiber/10G Ethernet/IP backbone with DSL (3-15M) last mile to each cabinet, NTCIP to controller
CCTV	215 cameras (SD, dome, color, PTZ) over digital fiber P-P link to TMC, TrafficLand video publishing to public, sharing with MD SHA and Mview
Additional ITS	Acylica (Sensys) WiFi readers along Montrose Rd smart corridor
TMC County Staff	Manager/Supervisors (2), Engineer (3), Operators (7), Systems Analyst (1), IT Tech (1)
TMC Contract Staff	IT/Network Support (2 FTE)
TMC Operations	Normal 0500-0030 (19.5 hrs. M-Sat); 0700-0030 (17.5 hrs.Sun)
Signal Shop Staff	Supervisors (2), Technicians (15)

4 Near Term Deployments

This Chapter focuses on establishing the foundational elements upon which future ITS capabilities may be supported while keeping an “infrastructure lite” approach. Recognizing the rapid changes in Information and Communication Technologies (ICT) as well as the rapid advancement in related transportation technologies and services the focus is to prepare for the future without inviting premature obsolescence. The near-term focus is therefore on proven technologies to manage signals, collect and archive data, and prepare for developing technologies. This Chapter will identify options, criteria and recommend courses of action.

The City is currently designing Transit Signal Priority (TSP) and has funding to implement Adaptive Traffic Signal Control (ATSC). With these investments, a host of supporting investments will be necessary. These immediate deployments need to support the TSP and ATSC procurements as well as future ITS deployments.

Based on Chapter 1 – Stakeholder Needs and Chapter 2- ITS Existing Infrastructure the options for near term investments fall into one of 12 Categories. Category 13 Connected Vehicles and Category 14 Autonomous Vehicles are discussed in the next Chapter.

This Chapter describes options and the preferred choice for the City. Where a preferred option is not discernible this Chapter lists criteria and guidance for selecting these technologies.

13) Transit Signal Priority (TSP)
14) Adaptive Traffic Signal Control (ATSC)
15) Traffic Signal Systems
16) Advance Transportation Management Systems (ATMS)
17) Detection
18) Controllers
19) Cabinets
20) Closed Circuit Television (CCTV)
21) Communications Backbone
22) Traffic Management Center
23) Parking Management
24) Information Devices (RWIS, Variable Message Signs, Becons)
25) Connected Vehicles (long term)
26) Autonomous Vehicles (long term)

4.1 Transit Signal Priority (TSP)

4.1.1 Overview

Transit Signal Priority (TSP) is an operational strategy that provides favorable signal timing and phasing to transit vehicles. The goal is to improve transit reliability and average speed with a minimal impact to corridor progression for general traffic. With improved transit service, more motorists will choose to use transit; this will remove vehicles from the network and improve the overall efficiency of the transportation network.

The existing systems consist needed to support TSP consist of the City traffic signal system, traffic signal controllers with TSP logic, and the DASH CAD/AVL vehicle components with real-time vehicle location, schedule adherence status, and passenger load information. Currently there are two types of systems. DASH uses GTT GPS radio and WMATA uses Clever Devices cellular modem.

Two basic components of a TSP are the Priority Request Generator (PRG) and the Priority Request Server (PRS). The Priority Request Generator (PRG) uses information communicated by the AVL system to determine if priority movement for the vehicle is justified and if so alerts the traffic control system that the vehicle would like to receive priority.

The Priority Request Server (PRS) processes the PRG request and decides whether and how to grant priority based on the programmed priority control strategies of the traffic signal system.

The City's scalable Transit Signal Priority (TSP) on Duke Street (DASH/WMATA) and US Route 1 (WMATA) is expected to be in place for DASH vehicles in 2018. In addition, Beauregard Street (WMATA) will have TSP for WMATA vehicles. With these corridors, the City will be gaining experience to inform expansion options.

4.1.2 Technology Options

There are various architectures and technologies that can be used to support this capability.

1) Decentralized Architecture. The traditional decentralized architecture places the PRG on the bus as part of the onboard Integrated Vehicle Logic Unit (IVLU) with the PRS located in the local traffic signal controller. Communications is directly between the vehicle and signal.
2) Centralized Architecture. With a centralized architecture the generator, the server or both are directed from a central traffic management system. This requires a capable Advanced Traffic Management System (ATMS), DASH CAD/AVL processing and communications infrastructure.
3) Centralized Architecture with a network-level optimization. This option adds the capability to develop optimal solutions to best move corridor traffic, to best reduce overall vehicle delay or other criteria.

Decentralized architecture is the least complex and easily implemented. However, it does not take advantage of a centralized system that has awareness of the entire network. The centralized architecture has greater potential to use TSP in conjunction with other systems to meet the overall TSP goal.

Currently the City is developing TSP along Duke Street (DASH Route 8). WMATA Route 7 is already operating TSP along US Route 1 and Beauregard / Seminary Streets.

4.1.3 Expansion Criteria

The following criteria will inform decision makers in selecting additional corridors for TSP:

- Dedicated Bus Lane – TSP works very efficiently in conjunction with uncongested dedicated bus lanes. When the bus is impeded by general traffic the benefit of signal preference is much less.
- Bus Route Frequency (headway) – TSP may be difficult to justify with too few buses per hour.
- Near-Side Far-Side Bus Stops – research has found that effectiveness of TSP decreases with near-side stops. The impact of bus stop location can be controlled somewhat by utilizing door open/closed status as condition for TSP requests.
- Unreliable Bus Speed – TSP should be targeted where approaching bus link speeds are highly variable compared with the route average.
- Slack Time – there must be some flexibility in the traffic signal timings to be able to re-allocate time and respond to the TSP request.
- Ridership – TSP should be targeted on routes with high ridership or the potential for higher ridership. TSP with routes with low ridership that do not serve major employment areas will not effectively increase person throughput. Person throughput performance can also be improved by using real-time passenger load as a conditional TSP parameter.
- Bus Rapid Transit (BRT) – Where BRT routes are not on physically separated lanes TSP is needed to help keep the buses on schedule. Currently BRT planning and design is underway for Van Dorn Street.

Using this criterion, several corridors are logical candidates for expansion. DASH Route 5 and 6 on King Street and DASH Route 2 on Janney-Seminary are good candidates. Design to implement Bus Rapid Transit (BRT) on the Van Dorn corridor may require TSP where separate lanes are not possible. Expand DASH TSP along Seminary, Beauregard, Rt 1 and anywhere where WMTATA TSP is already operating.

4.1.4 Conclusions and Recommendations

Transit Signal Priority (TSP) will improve transit reliability and average speed and help to increase transit ridership. The City's ongoing TSP projects will provide lessons on how to fully take advantage of this technology.

With the addition of Adaptive Traffic Signal Control and improvements in the Advanced Traffic Management Systems (discussed in the next two sections) TSP will be important part of an overall system to improve network efficiency. Two additional corridors – King Street and Janney-Seminary are good candidates to extend the use of TSP. The preferred architecture should be further investigated and will be based in part on the selected traffic signal controller, traffic signal system, and DASH CAD/AVL vendor capabilities.

4.2 Adaptive Traffic Signal Control (ATSC)

Adaptive Traffic Signal Control is programmed for funding through the Virginia Commonwealth Smart Scale program. The City received approval in the both the 2014 Smart Scale (known as HB2 at that time) round and the latest 2016 Smart Scale round. The approvals are for $7.0 and $7.675 million.

The areas and corridors are shown in the map. The project was scoped for HB2 and Smart Scale purposes, however additional planning, cost estimates and phasing is needed. An ATSC plan should be developed to confirm the cost to implement ATSC at the locations shown, prioritize corridors and areas, and determine the overall concept for implementation.

4.2.1 Overview

Adaptive control is a form of traffic signal operation in which phase times of a signal system are continuously adjusted in response to real-time traffic demand to optimize an objective function (progression, throughput, stops, delays, operating cost, emissions, etc.). It has shown much benefit on the peak-period fringes – the one to two hours leading up to and following the peak period and during incidents or other abnormal traffic patterns.

ATSC has been shown to yield performance improvements of 10-15% over a well-maintained and timed conventional system. However, heavy pedestrian traffic, inefficient intersection geometry, and high Volume/Capacity (V/C) ratios (generally above 90%) may limit this improvement. The application of ATSC should also be considered along with possible deployment of Automated Traffic Signal Performance Measures (ATSPM). ATSPM provides the automated tools to analyze individual intersection performance metrics using hi-resolution traffic signal controller data and make timing changes in response. In effect this is essentially using human analytics to perform more frequent timing changes. ATSPM may be desired for less critical intersections or in locations where ATSC B/C was not justified.

4.2.2 Technology Options

There are over a dozen commercial-off-the-shelf (COTS) ASCT systems available ranging from corridor-based ACS-Lite type systems that make fine tuning adjustments to a running timing plan, to more capable systems that can address more varied traffic situations and networks. Although the data processing architectures, features and capabilities vary, all require significant detection and network communications to each intersection. Detection is all based on infrastructure point detection at the stop bar and in advance (typically 7 seconds in advance or about 400 feet).

The Multimodal Intelligent Traffic Signal System Project (MMITSS), while still an ITS research demonstration project, is the only system using connected vehicle detection to ascertain all traffic approaching the intersection and making adaptive decisions based on vehicle type, location, approach and velocity. As connected vehicle penetration continues it can be expected that this will also become a data source with existing and new adaptive systems. The increased use of the advanced transportation controller and peer-peer broadband communications will also most likely result in more adaptive control capability being "built-in" directly with the traffic signal control software.

4.2.3 Corridor Options

Eight corridors were proposed with the City's Smart Scale application. These corridors, from east to west are:

1. Washington Street
2. Route 1 Jefferson-Davis Highway
3. East – West Streets in Old Town – King/Prince/Duke Streets
4. Duke Street
5. Eisenhower Avenue (east)
6. Van Dorn Street
7. Beauregard Street
8. Route 7 King Street vic I-395.

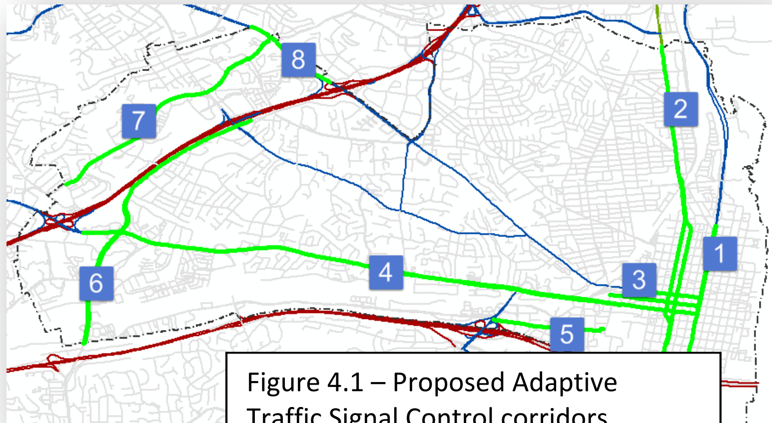


Figure 4.1 – Proposed Adaptive Traffic Signal Control corridors.

With the TSP upgrades to Duke Street and Route 1 Jefferson-Davis Highway, these corridors are a logical selection for the first two corridors. However, there are many other criteria and factors to consider to determine which corridors should be the highest priority. The FHWA ATSC systems engineering criteria outlines a process to determine which corridors best meet the City's objectives and goals.

As an initial guide, the following table provides essential traffic information for each corridor:

Table 4.1 Potential Transit Signal Priority Corridors					
Corridor	Length (miles)	AADT	Number of Signals	PM Peak MPH*	Transit Use (No. of Rts)
Washington Street	1.6	32,000	21	14.1	3
Route 1 Jefferson-Davis Highway	2.8	38,000	37	8.1	3
East – West Streets in Old Town – King/Prince/Duke Streets	2.3 (est)	20,900	25 (varies)	Varies 5.9 King St	Varies – 4 on King St
Duke Street, not Old Town	5.1	55,000	26	9.3	3 / 4
Eisenhower Avenue (east)	1.0	17,000	6	Not Avail.	2 / 3
Van Dorn Street	2.1	31,000	11	13.0	3
Beauregard Street	2.6	17,000	12	Not avail.	Varies
Route 7 King Street vic I-395.	1.2	45,000	5	8.8	3

** Average speeds based on RITIS, 4:00 PM averages for October 2017. Average speeds vary by link; slowest link selected. See map page 4.7.*

4.2.4 Conclusions and Recommendations

Selection of a COTS ASCT should be based on a multi-step screening process including technology and corridor selection. Initial technology selection should take into consideration controller and cabinet platform support, central integration capability with ATMS layer, and an analysis of capabilities using the FHWA ASCT systems engineering criteria as a guide. This process will also determine which of the eight corridors best meet the City's objectives.

4.3 Traffic Signal Systems

The Traffic Signal System (TSS) communicates directly with the traffic signal controllers and forms the cornerstone of the City traffic signal system operation. The City currently uses the Siemens TACTICS TSS along with Siemens/Eagle traffic signal controller to manage their signalized intersections. The TSS may also integrate ATSC and TSP functions described elsewhere or these functions may be supported on separate standalone subsystems (especially ATSC) alongside the TSS.

4.3.1 Overview

There are currently six (6) (Econolite, Intelight, McCain, Peek, Siemens, and Trafficware) US NEMA based TSS vendors with each of these supplying both the traffic signal controller and central software systems. There are other vendors, such as Forth Dimension (D4), supplying only the controller firmware, or Kimley-Horn supplying only the central software system. Historically, these systems needed to be purchased together as a system due to the use of proprietary communications protocols. With the use of the NTCIP suite of protocols this is no longer necessary and the City may select each independently based on the preferred features.

4.3.2 Technology Options

Most TSS platforms provide the following similar basic system functionality that compliments the capability of the traffic signal controller:

- Signal Status Monitoring (vehicle, pedestrian and controller unit status),
- Commanding (controller mode, patter, action plan, special functions),
- Time broadcast to maintain common controller clock time,
- Controller Database Editor supporting parameter management and upload/download,
- Traffic analytics and optimization (time space and split monitor tools),
- Scheduler to schedule recurring and future traffic control events and commands,
- Event logging and alerting (email, popups),
- Detailed reporting (signal status, communications status, actions).

The TSS should also provide advanced support for TSP, ATSPM, and ATSC among other functions. In addition to the basic systems functionality, any new TSS should also contain support for the following:

- NTCIP and other open protocol support – this will be critical to the integration with other ATC and firmware packages as well as the ATMS layer,
- Ability to integrate with other third-party traffic signal controllers. Many TSS vendors while supporting NTCIP do not openly integrate well with other controllers, most noticeably with the Controller Database Editor,
- Open Source Maps – more TSS solutions are going towards open GIS map solutions for the graphical user interface (GUI) to simplify map maintenance.

4.3.3 Conclusions and Recommendations

VDOT recently selected a new state-wide ATC traffic signal control firmware standard, and is now in the process of developing an RFP for statewide selection of a standard TSS. All state municipalities are able to take advantage of purchasing from the state contract for ATC and controller firmware, and will be expected to do the same for the TSS once that selection is finalized. As these systems can be complex and costly, and recognizing that VDOT has some similar requirements, it may be best for the City to delay any decisions to upgrade the TSS. In the meantime, the City may request to participate or at least monitor the VDOT TSS specification and selection process to determine a final direction.

Although VDOT's decisions should be considered, the City has its own needs and requirements. The systems engineering (SE) process should be followed to select the TSS system that is optimal for the City.

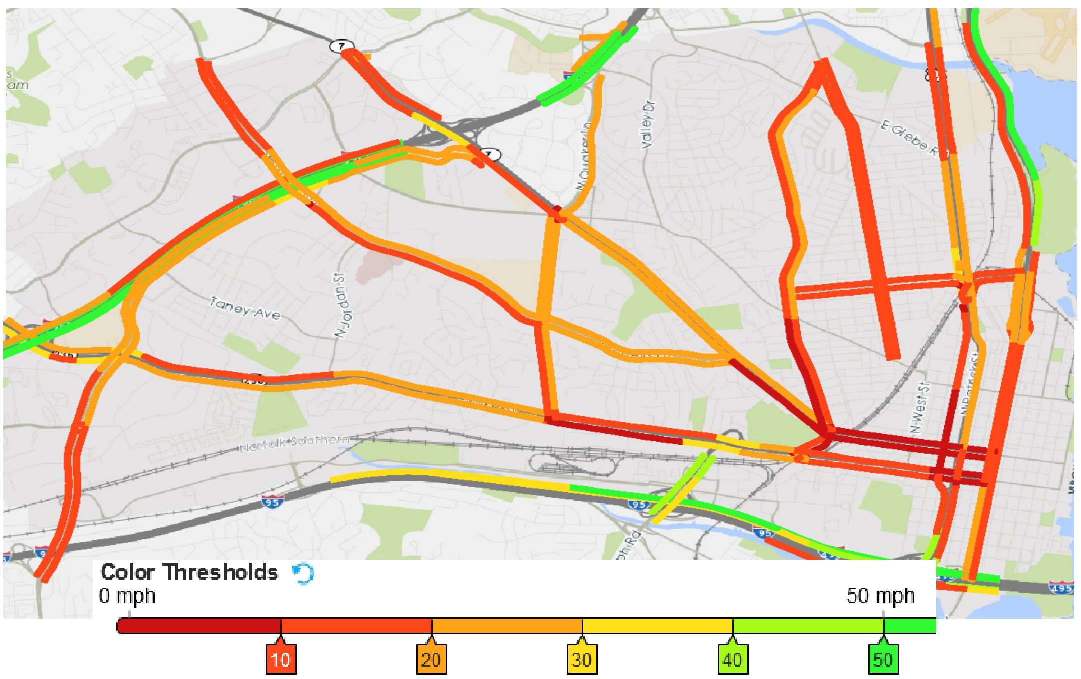


Figure 4.2 - Average Speeds, 5:00 PM October 2017. Source: RITIS Vehicle Probe Module

4.4 Advanced Transportation Management Systems

The Advanced Transportation Management System (ATMS) will integrate ITS devices, software subsystems, and data to help TOC operators maintain situational awareness over the entire transportation network, operate/activate ITS devices, and communicate with stakeholders. The ATMS will be the primary interface through which operators interact with the system and will be critical to the integration of the City's Transit System Priority (TSP) and Adaptive Traffic Signal Control (ATSC) and includes ITS systems for corridor management applications for multimodal and multiagency transportation systems, incident management, recurrent and non-recurrent congestion and integration with data collection systems.

4.4.1 ATMS Selection Criteria

As discussed in Chapter 2, there are currently multiple application-specific software subsystems in use by the City. The proliferation of additional subsystems compels the City to investigate ATMS options to integrate these operations.

The optimal ATMS system will meet the following criteria:

- Modular, secured web-based platform.
- Proven and well supported system.
- Easily upgradeable and expandable.
- One uniform interface with a wide range of devices and systems.
- Integrate ATSC, TSP, VMS and CCTV and advanced traveler information systems without performance degradation or maintenance issues.
- Compliant with NTCIP standards and other open standards.
- Use the City's traffic network to communicate to the field devices.
- Remote accessibility via web browser.
- Secure from cyber intrusion.
- Limited required systems administration support with transparent upgrade process of applications and operating system patches.
- Ability to share information with other regional transportation agencies.

4.4.2 ATMS Subsystems and Capabilities

The ATMS will be the integration point for all City transportation information and systems, it will serve as the primary TMC operator interface and provide analytical and reporting tools. It may also contain some core functionality, such as road closure, incident management, and control of devices. A main map interface will provide overall transportation situational awareness.

The following is a brief description of the subsystems and capabilities to be integrated. A more detailed operations concept and requirements analysis should be performed to develop the appropriate contracting documents to procure and integrate this capability:

- Lane Closure Advisory Management System (LCAMS) – VDOT is making LCAMS available to local municipalities. The primary interface would be a geospatial map whereby all subsystem information may be geospatially located to provide situational awareness.
- CCTV Video Management System (VMS) – The existing Bosch VMS includes an Application Programming Interface (API) to expose the pan/tilt/zoom (PTZ) camera control functions to the ATMS interface. Likewise the video can be easily multicast from the camera or network to display on the ATMS layer. Setup and control functions would remain with the Bosch VMS.
- Traffic Signal System (TSS) – Any new TSS such as adaptive traffic signal control, will integrate signal status and control functions through an NTCIP C2C exchange service utilizing the Traffic Management Data Dictionary (TMDD) standard. The system will report the signal status such as active control mode (local and system coordination, manual, free, flash, and adaptive), running pattern, communications status, alarms (door open, MMU flash), and TSP and emergency vehicle preemption status.

- Traffic Surveillance System – Traffic monitoring and data collection, either via in pavement or other infrastructure based detection or via probe methods such as Blue-Tooth, WiFi, or future DSRC, can be integrated into the ATMS layer using NTCIP C2C TMDD. Infrastructure generated data could be integrated and exchanged directly with the RITIS to generate a real-time roadway link level conditions map (red, yellow, green congestion information).
- School Flasher – the City currently operates a cloud-based school flasher system that provides for schedule changes and real-time monitoring. The real-time status could be displayed on the ATMS conditions map.
- Roadway Weather Information System (RWIS) – this will show status of roadway environmental conditions where available on the ATMS conditions map. Integration would be dependent upon available API or possible database read access.
- Fleet Vehicle CAD/AVL – this is the vehicle location system used to manage City maintenance vehicles and snow plows. Integration of vehicle location status into the ATMS allows operators to manage dispatch operations relative to overall transportation conditions.
- External Agencies – The ATMS will need to exchange data with VDOT, Arlington, WMATA and a regional system such as RITIS. The City may need to know freeway congestion, incidents, DMS sign status, and other control element status that may affect City traffic. Similar data exchange with Arlington County especially near jurisdictional boundary points along shared arterials will be important. DDOT and WMATA integration are deferred until a later phase.
- Parking Management – space availability in public garages, on-street, possible wayfinding, and possibly bike share information.
- DASH bus CAD/AVL system to support transit signal priority (TSP). Integration should follow the NTCIP 1211 standard which allows for different architectures, the details of which are dependent upon a deeper analysis of TSP options.
- Emergency Operations Center - The City EOC would be equipped with an ATMS workstation providing the DOT liaison with immediate access to all transportation network information during emergency operations.
- Traveler Information – transportation related status used for traveler information may be supported through the City web site or also through the VDOT smarter roads data portal (http://smarterroads.org). Since VDOT already has a regional mechanism for sharing public data out to potential third-party users it may be easier to simply feed information to this portal and avoid the complexity of adding these capabilities. This also ensures integration with other VDOT applications such as 511.
- Analytics and Performance Reporting – MAP-21 requires greater use of real-time and archived data to support development and monitoring of key Performance Metrics (PMs). These PMs may be generated by various subsystems and then maintained and reported through the ATMS. For example, RITIS for corridor PMs (i.e., travel time, speed, volume, congestion), and traffic signal system for signalized intersection PMs (i.e. delay, level of service). Future capabilities may include integrating this disparate data to develop cause and affect relationships to generate predictive capabilities.

A conceptual systems architecture with the ATMS as the focal point is shown below including a proposed phased integration. An investment in a new or upgraded ATMS is a near term need as well as subsequent expansion to support all capabilities.

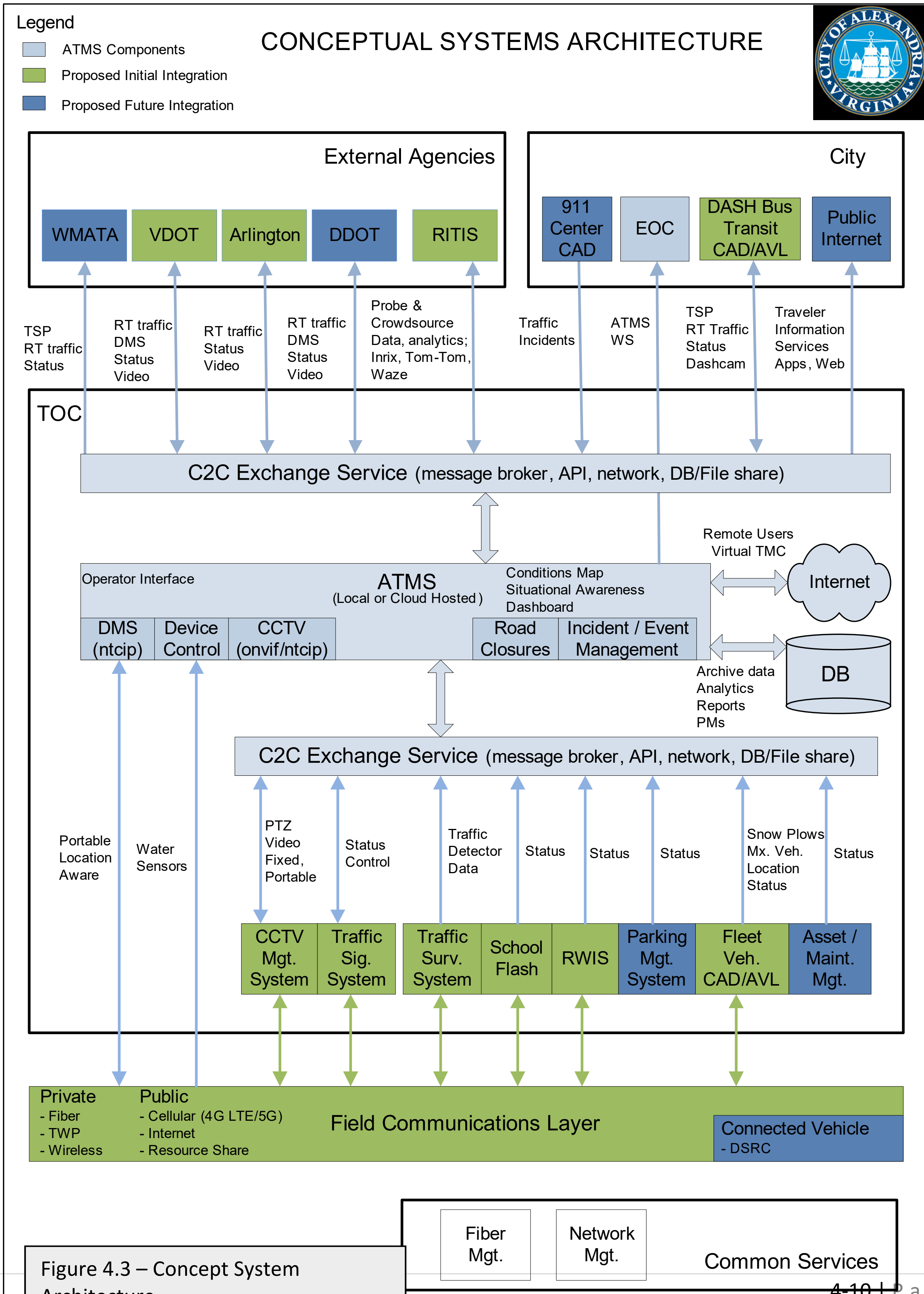


Figure 4.3 – Concept System Architecture.

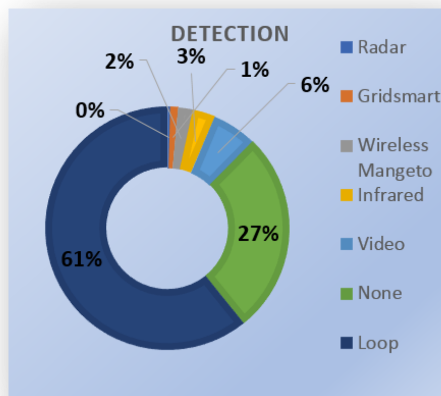
4.5 Detection Options

Anything that needs to be managed, needs to be detected. Detection types vary based on application need, as such a careful examination of need should precede any decision on detection selection. Technologies also continue to rapidly evolve and so a variety of detection types and technologies can be expected over the life of any system. Detection technologies also have their inherent strengths and weaknesses based on the underlying technology capabilities and limitations. Therefore, a technology that may be appropriate for one application may not be for another.

4.5.1 Vehicle Detection

The City has a need to detect vehicles, bikes and pedestrians at intersections and in the transportation system. Vehicle detection is well established, using a wide range of technologies, at the City's intersections. As such the critical question for vehicle detection is:

- Should the City convert to one detection technology at intersections?
- What technologies are available to determine vehicle volumes and average speeds for planning and operational purposes?
- How do Connected Vehicle technologies influence near term decisions?



Should the City convert to one detection technology at intersections? The City uses inductive loops for most of its detection. However the other technologies – radar, wireless magnetometer, infrared and video – have also been used with varying levels of success in their applications. Each technology has its strengths and weaknesses and the City has pinpointed the use of each. Although maintenance is more complicated, there is no compelling reason for the City to settle on one technology for intersection control, but instead maintain several options in its toolbox.

What technologies are available to determine vehicle volumes and average speeds for planning and operational purposes? Currently the Regional Integrated Transportation Information System (RITIS) uses probe data to provide both real time and data archive. This system meets the City's needs for major roadways. However, RITIS provides limited coverage on local streets. Other probe vehicle detection includes Bluetooth and WiFi, and cell phone detection. Each could be used to supplement the data provided by RITIS.

How do Connected Vehicle technologies influence near term decisions?
Connected vehicles (CV) will provide a richer set of information (vehicle type, location, heading, speed, and possibly other status such as acceleration, braking, and steering wheel position) than is possible from infrastructure based point or re-identification detection. However, the roadway penetration of CV equipped vehicles will take some time and so for the foreseeable future infrastructure based detection will be required for signal operations.

However, for planning and many operational uses a sampling of vehicles may be sufficient. For this reason, infrastructure-based technologies such as Bluetooth and WiFi should only be deployed along critical routes on a temporary or permanent basis. When CV penetration reaches BT and WiFi levels (typically ~10%) then DSRC radios may slowly replace BT and WiFi radios. The backend data collection and processing application to generate link based speed, travel time, O-D information should remain largely intact as the data will be similar.

In addition to connected vehicle DSRC, several vendors are developing methods to collect and store data for minor streets. As such an investment in Bluetooth, wireless or other readers may be unnecessary even before wide spread use of vehicle DSRC.

The City uses a wide range of vehicle detection and does not have a compelling need at this time for widespread upgrade existing of existing intersection detection. The City also has access to real time and archived data for major arterials. The only shortfall for obtaining archived data is minor arterials and collectors.

4.5.2 Pedestrian Detection

The primary short term need for pedestrian detection is to add passive detection at intersections where it is currently missing. VDOT policy is to install passive detection at all intersections. Active detection, whether it be via infrared or radar, is not a high priority need for the City.

Detection of pedestrians to determine their volume and patterns does have benefits to the City. This detection would inform planners and be important in a future system. To provide the benefit of a general number of pedestrians by major roadway 10 to 15 detectors would provide a representative sample.

4.5.3 Bike Detection

Bike detection is also desirable at intersections to monitor volumes and speeds along designated bike routes and where bike volumes justify the added expense. Bike detection at intersections will allow bikes to place a call on the signal as well as provide the volume of bikes. Many technologies are available:

- Inductive Loops – Commonly used in Bike only lanes. Existing loops that detect vehicles are not arrayed to accurately detect bikes.
- Radar
- Wireless Magnetometer
- Infrared
- Video

Currently, there are no locations in the City where a lack of bike detection is causing issues for bikes. For planning purposes, short term deployments of counting devices would provide the necessary information.

4.6 Controllers

The City currently operates a mix of different traffic signal controller versions and vendors (see table). While there will be slight differences in capability and intersection capacity support most are able to perform similar traffic signal control functions based on the NEMA TS1 and TS2 standards.

Historically, the controller hardware and firmware were purchased together and the standards only defined the Input/Output functionality and not the internal design. As such the controller hardware and firmware were proprietary to the vendor. Likewise, the use of proprietary communications protocols meant that the controller hardware/firmware and TSS needed to be purchased from the same vendor. With the advent of the ATC and use of open standard communication protocols those restrictions no longer apply.

Table 4.2 - Controller Inventory

EPAC 300	52%	132
m50	34%	87
Other*	8%	20
m52	6%	15
Total		254
* as of September 2017		

4.6.1 Controller Options

The industry standard controller had been the NEMA TS2, however this standard is being supplanted by the Advanced Transportation Controller (ATC) as defined by AASHTO in conjunction with the Institute of Transportation Engineers and NEMA[4]. The ATC reflects advances in computing technology and was developed to effectively replace the NEMA, and Model 2070 controller standards with a truly open platform environment that separates the controller hardware and software so that these may be procured from different sources. The ATC also specifies a standard Application Programming Interface (API) to allow multiple applications to reside on the same hardware platform while simultaneously accessing the common field I/O and user display modules. This will allow a connected vehicle application to run on the same hardware platform as the signal control software, and for each to be from different vendors. The ATC also contains a more capable engine board with higher end microprocessor and more memory, along with expanded I/O capability such as USB and Ethernet ports. Most vendors are developing new traffic signal control features for their ATC platform and many have already defined end-of-life, and end-of-support schedules for their older NEMA TS2 controllers.

4.6.2 Controller Replacement Plan

Based on general industry direction and the need for future advanced controller functionality the ATC platform offers the City the most flexibility and capability. In addition, VDOT recently selected a new state-wide ATC traffic signal hardware (McCain and Econolite) and firmware (Forth Dimension) standard and approved vendors. All state municipalities can take advantage of purchasing from this new state contract. There are economies of scale in purchasing off the statewide contract which will result in lower per unit cost than what would otherwise be available. Likewise, maintenance and support can be expected to also be better with such a large installation base.

New ATC controllers should be placed on the corridors with the most demand for Intelligent Transportation System features (TSP, ATSC, ATSPM). Controllers can be moved between signals, as such where the new controllers replace the m series controllers, the m-series can in turn be used to retire the oldest TS1 controllers (EPAC 300 and other) controllers.

[4] AASHTO/ITE/NEMA; Advanced Transportation Controller (ATC) Standard Version 6, June 2018.

Signals along Duke Street and Route 1 Jefferson-Davis Highway are to be replaced first as part of the TSP project. Next will be those corridors that will implement Adaptive Traffic Signal Control.

4.7 Cabinets

The City currently has a mix of older NEMA TS1 and newer TS2 Type 2 cabinets including base and pole mounted units. The cabinets are generally backwards compatible with the newer style controllers so that NEMA TS 2 Type 2 controllers can also operate in older TS1 type cabinets.

Table 4.3 Cabinet Specifications

	Detector Channels	Output Channels
NEMA TS-1	24	16
NEMA TS-2	64	16
ATC	120	32

4.7.1 Cabinet Options

The NEMA TS2 cabinet remains the most popular in the industry and is slowly replacing the older NEMA TS1 cabinets still in use. The NEMA cabinet standard mirrors the similar NEMA controller standard in that the controller to cabinet input/output (I/O) interface is fully standardized (function, electrical, mechanical) to ensure complete interoperability. Furthermore, the serial interface standard of the NEMA TS2 greatly expands the I/O capacity over the older NEMA TS1 cabinet.

The ATC Cabinet (ATCC) is part of the ITE/NEMA/AASHTO suite of ATC standards and is intended to eventually replace all other cabinet types: NEMA TS1, TS2 and Caltrans 33x. The ATCC is an open architecture traffic control cabinet that offers significant improvements in cabinet modularity and compact size, motorist safety, technician safety, and diagnostics capability. Version 2 of the standard (ATC 5301 V02) is currently under development.

Security will continue to be at the forefront of ITS including the traffic signal cabinets. As these field enclosures become more of an aggregation point for many transportation related services and as more of these services are being networked, security will become more critical. VDOT is beginning to investigate cybersecurity cabinet access solutions which will result in a new standard that is expected to eliminate simple key access.

4.7.2 Cabinet Recommendations

For the immediate future, any new cabinets should continue to be the NEMA TS2 type. The City should consider the ATCC only as the ATCC V2 standard matures, as VDOT migrates towards the ATCC, or for very specific applications that may be difficult to satisfy with the NEMA TS2. Specific applications include intersection I/O density not supported by the NEMA TS2, or need for a compact central business district (CBD) type cabinet. Until the ATCC standard matures the City should expect the V1 cabinet parts may not be interchangeable among vendors. The ATC Controllers are adaptable to NEMA TS1, TS2 and ATC Cabinets and so a future upgrade of the cabinets will not impact use of the ATC now.

Unlike controllers, cabinets are not easily swapped from location to location due to mounting differences, conduit, and cable routing. As such, careful consideration should be made prior to phasing in newer cabinets. Priority of replacement should have the following pattern:

1. Replace NEMA TS-1 cabinets on an as needed basis with NEMA TS-2 Type 2 on high priority corridors such as Duke Street and US Route 1 Jefferson Davis Highway (TSP project).
2. Replace NEMA TS-1 cabinets on an as needed basis on lower priority intersections.

3. Introduce ATC cabinets once the standard matures, as VDOT begins to migrate toward the ATCC, or under specific applications that cannot be supported by the TS2 standard

Of the 254 traffic signals in its inventory, 144 use a NEMA TS-2 Type 2 Cabinet. The remaining 110 signals use the NEMA TS-1 controller cabinets.

4.8 Closed Circuit Television (CCTV)

Closed Circuit Television (CCTV) provides real-time traffic condition information quickly and cheaply both for operational decision making and traveler information. With the completion of Phase IV, there will be fiber connections to 113 signals. Fiber will be completed in place, but not fully connected to an additional 39 signals[5].

CCTV to every fiber connected signal is possible however there are connection, maintenance, management and storage requirements for each camera. As points of reference, Arlington County has 182 cameras, Montgomery County, Maryland has 215 cameras, City of Wilmington North Carolina has 34 cameras[6]. The value of the additional cameras depends on the proximity of the signals, video feed storage policy, and other systems on the corridor.

4.8.1 Overview

Camera technology has advanced significantly over the last few years driven mostly by the security industry. Continued miniaturization of electronics has resulted in more functionality being packaged in the camera housing at lower cost than ever before. The major cost component, and impediment, of deploying more cameras is adequate broadband communications. Assuming broadband communications is available at the traffic signal cabinet, then there is only a small marginal cost to add camera video at that location.

Video compression standards, based on the ubiquitous H.264, means that better higher resolution image and motion quality can be supported at lower bandwidths. The H.264 standard also ensures interoperability between camera, network, and central video management system. Many camera systems are now also moving towards HD (1080) or UHD (4k) image resolution. Although not required for general traffic surveillance these higher standards result in clearer images. The ONVIF (Open Network Video Interface Forum) standard also ensures interoperability of all camera functions. While there is a similar NTCIP standard, ONVIF has a broader adoption mainly driven by the securities market.

4.8.2 Recommendations

The central Bosch video management system appears to have all the necessary functionality and expansion capacity required by the City. The Bosch dome cameras also conform to all of the latest standards. The City should continue to deploy these cameras on a prioritized and as needed basis based on following criteria:

[5] Phase III and Phase IV are expected to connect signals to the fiber run in Phase I and Phase II. Phase I and Phase II run fiber to 113 signals. Phase III and Phave IV will run fiber to an additional 39 signals.

[6] Bennett, D. City Traffic Engineer, Wilmington, NC. ITE Bulletin Board “CCTV Recording policies and procedures”; 27 October 2017.

- Based on operational need (recurring congestion, major or critical corridors especially with advanced control modes such as TSP or ATSC, complex or critical intersections, along designated evacuation or alternate routes, special event venues, and jurisdictional boundaries).
- Along signalized corridors to provide some video visibility.
- Along fiber routes or other high bandwidth locations (DSL connected cabinets).

Current practice is to place cameras on signal poles at intersections. This practice is most cost effective as power and communications are available, and intersections are points of interests. However, other locations such as on City Hall or another high vantage point will provide good visibility of Old Town.

Based on the above criteria the eight corridors planned for Adaptive Traffic Signal Control are a priority for CCTV. The table below is a minimal plan to add 31 cameras to provide coverage for every signalized corridor without signalized gaps.

Storing the video has value to verify incidents, plan for special events, and to improve operations. The video also has value to law enforcement. However, the City should carefully consider the cost-benefit of adding recording capabilities as compliancy to meet legal requirements can add to increased staffing workload. FHWA has recently issued best practices guidance for recording, storing and sharing video in the report "Transportation Management Center Video Recording and Archiving Best General Practices"[7]. Arlington County currently does not store video feeds, as such their approach is to have many cameras, but without archiving. The FHWA Best Practices Guide provides examples of All, Some or No storage.

[7] Kuciemba, S., Swindler, K. (2016). *Transportation Management Center Video Recording and Archiving Best General Practices. FHWA-HOP-16-033.* U.S. Department of Transportation Federal Highway Administration.

Table 4.4 - CCTV Camera Current and Planned			
Corridor	Current CCTV	Minimal Additional*	Notes
Washington Street	2	2	Good coverage in Old Town
Route 1 Jefferson-Davis Highway	3	4	Approx. 1 per 4 blocks
East – West Streets in Old Town – King/Prince/Duke Streets	3	6	Additional needed east and west of Route 1
Duke Street	3	3	Monitor Adaptive Control
Eisenhower Avenue (east)	1	3	Long corridor.
Van Dorn Street	1	1	Edsall Rd and north of Landmark
Beauregard Street	2	2	Coverage of ½ of signals
Route 7 King Street vic I-395.	3	5	Currently well spaced.
Non Future Adaptive corridors			
Seminary Road	2	2	Need coverage via I-395. Transit Route.
West Braddock Road	1	1	No communications currently
Mount Vernon Avenue	0	2	No communications currently
Eisenhower Avenue (west of Telegraph Road)	0	2	
Total**	**21**	**33**	

* Approximate number of additional cameras to provide coverage without significant gaps
** Current and design underway. Total is 25; some are counted on more than corridor.

4.9 Communications Backbone

Communications is typically the greatest cost element of any traffic signal control and ITS system. With advances in technology the communications networks are becoming more capable and can connect all services across a single integrated network. A properly designed broadband communications network where everything may be interconnected is the single most important investment to prepare the City to support future transportation services.

4.9.1 Overview

The Communications backbone consists of two distinct elements: 1) the Field Network, and 2) the Central IT Network. The defining characteristics of the Field Network include:

- Harsh environment requiring use of industrial grade hardware (NEMA TS2),
- High security with each traffic signal cabinet,
- Broadband to each traffic signal cabinet with a minimum of 100Mb at each cabinet,
- High port density at each traffic signal cabinet to support current and future applications:
    - Traffic Signal Controller,

  - Uninterruptable Power Supply (UPS),
  - Smart Detection (video image detection, magnetometer, radar, APS),
  - Smart Multifunction Management Unit (MMU),
  - Closed-Circuit TV Camera (CCTV),
  - Blue-tooth, WiFi re-identification reader,
  - Additional processor or logic (i.e., ATSC),
  - TSP PRS (i.e. Phase Selector),
  - DSRC RSU (Connected Vehicles).
- Typically managed by field technicians also responsible for the cabinet,
- Communications ducts and in some cases fiber will be shared with IT.
- Operations typically monitored by DOT personnel.

The defining characteristics of the Central IT Network include:

- Higher bandwidth core network (typically 1/10 GigE) supporting the application server and workstation environment,
- City-wide network access to support operations and maintenance users of the systems,
- Internet access to support cloud-hosted applications, remote operations and maintenance access, and public communications field network access (i.e. cellular),
- Isolated by Firewall from the Field Network,
- Shared by other City services and general City IT functions, not just traffic,
- Typically managed, operated and maintained by City IT staff.

4.9.2 Technology Options

There are several different field communication technology options.

<u>Communications Media</u>. Fiber has been and will continue to be the medium of choice due to its great bandwidth carrying capacity, high security, and low operations and maintenance costs. Single-mode fiber has mostly replaced any further use of multi-mode in the field network due to convergence of costs. Fiber/Ethernet (100Mb/1GigE typical) and Gigabit Passive Optical Network (GPON) are the most popular transport technologies. GPON, made popular in the fiber-to-the-home market, has not been widely used in transportation, but the architectures and needs are very similar, it has a lower capital cost, and there are other possible benefits in the areas of maintenance. The City is currently running a few circuits with GPON technology supporting mainly Traffic Signal Control.

Copper twisted wire pair (TWP) cable continues to be in widespread use. Advances in bandwidth carrying capacity have been made possible with technologies such as Digital Subscriber Line (DSL) and have extended the usefulness of this medium. The City is currently running some “last mile” DSL circuits using Ruggedcom VDSL modems to connect traffic signal cabinets to the nearest fiber access points. In addition, some DSL equipment supports bonding of multiple copper pairs providing increased bandwidth. In addition to increased bandwidth, by utilizing all pairs, the communication network is also able to monitor the condition of the entire cable network.

Private wireless options supporting broadband communications vary from licensed (700MHz and 4.9GHz public safety, microwave) to unlicensed (typically 2.4 and 5.8GHz). Bandwidth capacity depends on the technology (power output, receiver sensitivity, and channel bandwidth) but also on radio link engineering (distance, line-of-sight, and obstructions such as tree foliage). Bandwidths up to about 300Mb/s are possible over short (1-2 mile) distances. The 5.8 band is one of many unlicensed bands, but the 5.8 band is typically less noisy than other lower bands and therefore less prone to interference. The 700 and 4.9 bands would be licensed through the City public safety radio licensing administrator, which is a relatively quick and no-cost process. These band are set aside for public safety applications including ITS with sufficient bandwidth capabilities to handle most any application. Vendors typically use their own proprietary channel encoding and frequency allocation scheme limiting vendor interchangeability, but as a result also increasing security. In addition, many units also add 128/256 bit data encryption schemes.

Cellular wireless provides a low-cost means of providing IP communications to any signal cabinet. It is best used as a "gap filler" for isolated intersections that do not cost-justify installing cable or may be difficult to reach with a private wireless solution. The current 4G/LTE download speeds are about 5-12 Mb/s and upload speeds of about 2-5 Mb/s. Future 5G services starting around 2021 will provide even greater capabilities. A virtual private cellular connection to the central IT network with proper firewall security provisions will be required.

<u>IP-based network.</u> While some serial devices still exist, these are quickly being replaced by Ethernet-IP communications as the universally supported technology. This simplifies integration into the central IT network with support for redundancy, peer-to-peer in addition to field-center communication traffic patterns, improved scalability and system expansion. Additional capabilities and support for advanced standards such as IPv6 will be driven mostly by the Internet-of-Things (IoT) market.

4.9.3 Recommendations

The following is the recommended priority order of field network communications technology deployment:

1. Extend broadband communications capability to all signalized intersections and ITS devices according to the following deployment criteria
    - <u>GPON fiber optic deployment along priority corridors where fiber exists</u>. All cabinets along these corridors should be directly connected to the fiber network.
    - <u>DSL at intersections that have copper TWP cable.</u> DSL is a point-point technology with the other end connected to the nearest fiber access point. DSL would function as a "last-mile" connection extending broadband connections to intersections not on the fiber cable. This may apply in the Old Towne area or any other locations where existing copper in Verizon C&P conduit may be repurposed.
    - <u>Private wireless (700 MHz licensed) for "last mile" connections</u> where cable does not exist with the far end connected to the nearest copper or fiber cable access points. Private wireless requires proper RF site engineering to qualify the site based on clear line-of-site (LOS) link path. The 700MHz public safety licensed band should be field trialed or pilot tested first before committing to a larger roll out.
    - <u>Cellular 4G/LTE for isolated intersections</u> where other options would be too expensive or impractical, and also for mobile and transportable assets such as Portable VMS. These would typically be less critical locations. This public carrier-based service would integrate through the central IT network and not over the City-owned field network as the other solutions.

2. Develop a *Communications Implementation Plan* that provides the details necessary to guide the phased deployment, configuration, and operation of this network. The plan would also identify demarcation points between the field network, the Central IT network, and other possible connecting networks and identify the various roles and responsibilities for operations and maintenance. This would include installing a purpose-built network firewall to adequately separate the Field and Central IT networks and allow for easier future expansion of system operations across the City.
3. Identify a suitable Network Management System to support operations and maintenance of the active network. As the network grows in size and applications support its importance also increases. Maintaining active oversight and being able to respond to outages will be important. This also includes identifying vendor-specific Element Management tools typically used to remotely interrogate and manage vendor-specific features of network equipment (i.e., firmware upgrades).
4. Identify suitable Fiber Asset Management GIS-based tool to support with the following functions. (Note: This Asset Management GIS is included in Phase III).
    - Identify exact location of fiber utilities and useful for asset management, planning, and troubleshooting analysis
    - Track fiber utilization, cable age and condition, and location of supporting infrastructure
    - Model connectivity of cable and fiber strands including splices and losses
    - Analysis and troubleshooting including diversity check, fiber trace, fiber outage locate, and logical distance measures.

The ongoing Phase I through IV places fiber, signal connections, CCTV, an asset inventory and other elements. A **Phase V** is needed to implement the recommendations above. The scope of Phase V:

- Create Communications Implementation Plan.
- Extend Fiber communications to missing corridors in accordance with Communications Implementation Plan. Section 2 identified the following corridors:
    - Eisenhower Avenue.
    - Duke Street, missing 2.0 miles.
    - Mount Vernon Avenue and Braddock Road, to be determined by alternatives analysis.
- Complete fiber deployment to data center locations such as the TMC, City Hall, EOC, transit centers; and other ITS field devices to create a future backbone for DSRC deployment.
- Extend broadband communications capability to all signalized intersections and ITS devices via GPON, DSL, Private wireless, Cellular 4G/LTE or Future 5G.
- Further expand ATMS capabilities including Parking and asset/maintenance management, incident/event management, CAD incident data integration, further dashboards.

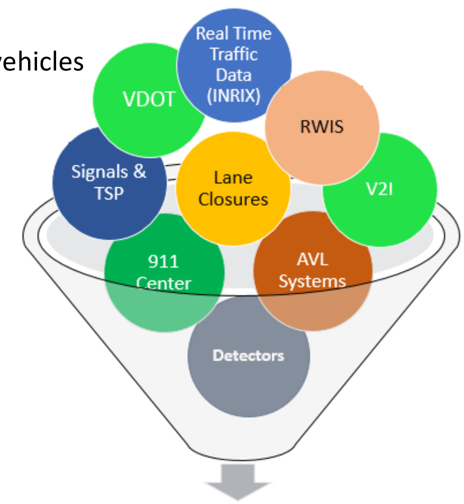
4.10 Traffic Management Center

The City's smart traffic system will be monitored and controlled in the Traffic Management Center (TMC). The Architecture for the myriad of systems and the Advanced Transportation Management System is shown in Figure 4-3 "Conceptual Systems Architecture".

4.10.1 Traffic Management Center Requirements.

During the Stakeholder meeting, the Stakeholder group established the following needs for the TMC:

- Monitor and Control Needs:
  1. Control signal timing and phasing.
  2. Control Variable Message Signs (VMS).
  3. Monitor Automated Vehicle Location (AVL) information on city vehicles
  4. Manage dispatching of Public Works vehicles.
  5. Monitor real time conditions, primarily via Conditions Map.
- Conditions Map Needs:
  1. Traffic conditions (congestion, average speeds);
  2. City vehicle locations via AVL.
  3. Incidents (detection, response, manage, close);
  4. Work zones (location, type, duration;
  5. Maintenance and snow removal vehicle locations and status;
  6. Status of signals, detectors, and other ITS infrastructure;
  7. School flashers (schedule and status);
  8. Roadway weather conditions (RWIS);
  9. High water sensors.



Conditions Map

In addition to these Needs, the Stakeholder Group and City Staff articulated a vision for the TMC with the following features:

- Intelligent systems (i.e., ATSC) making real-time changes to traffic control parameters in response to real-time conditions based on established policy.
- Engineering staff overseeing strategic and trending operational changes in response to policy and performance measures analysis rather than merely responding to real-time conditions. Existing engineering staff, rather than dedicated operators, would oversee this operation.
- Systems that can gracefully adapt to field equipment failures - such as detection or communications - because of redundant design and automated failover capabilities. This includes redundant central systems located in diverse locations.
- Maintenance staff being automatically notified of system failures with ability to assess impact and urgency of repair based on designed redundancy and failover capability. The goal is to shift most repairs toward routine maintenance to control costs and staffing levels.
- **Virtual TMC capability** whereby all these systems and tools would be remotely available to authorized staff so that physical building access is no longer a limitation to performing these functions.

4.10.2 Conditions Map Alternatives.

The Conditions Map data will be provided largely from the Advanced Transportation Management System (ATMS). The elements that the ATMS either directly controls or interfaces with all the elements that need to be shown on the Conditions Map. These elements are described in more detail in Section 4.4.2 ATMS Subsystems and Capabilities.

The most fundamental feature for the Conditions Map is roadway congestion. Google Maps, WAZE and other providers of web-based mapping programs provide reasonably accurate. The Regional Integrated Transportation Information System (RITIS) is better able to aggregate information from multiple sources, including agency infrastructure data, to create a more accurate assessment of congestion for City arterial corridors, neighboring jurisdictions, and local VDOT facilities. RITIS is also able to incorporate incident and work zone information into the overall picture. The ATMS has visibility of much of the remaining City's ITS elements.

Many ATMS's have modules to show a wide range of asset status and real-time information. On the following page *Table 4.5 - Typical ATMS Vendors* that shows the advertised modules and capabilities from two ATMS vendors.

Table 4.5 demonstrates that many of the Conditions Map requirements can be met by the ATMS system with off the shelf modules. As expected, the ATMS based modules do not show real time data not related to the signals. One did have a module for use with a supplementary Blue Tooth device. As a result, real time AVL vehicle locations, work zones, snow removal status and other sensors integration will be dependent upon available Application Programing Interface (API) and database access.

The Conditions Map will require integration of three sources:

I. Conditions Mapping from Google Maps (or equivalent) and RITIS,
II. ATMS Modules,
III. City ITS subsystems, such AVL or RWIS.

Once the selection of the ATMS is complete, the process to integrate these three elements can be determined.

4.10.3 Monitor and Control Alternatives.

Five general requirements were established to be performed by the TMC:

1. Control signal timing and phasing.
2. Control Variable Message Boards (VMS).
3. Monitor Automated Vehicle Location (AVL) information on city vehicles.
4. Manage dispatching of Public Works vehicles.
5. Monitor real time conditions, primarily via Conditions Map.

Control signal timing and phasing. This fundamental requirement will be controlled by the Traffic Signal System (TSS) in conjunction with the ATMS. This is a core requirement of the ATMS.

Control Variable Message Signs (VMS). The City does not currently have a fixed Variable Message Sign, but does maintain Portable Change Message Signs (PCMS). The TMC requirement is to be able control and monitor messages on electronic signs or boards of any type, and to also monitor signs from other neighboring jurisdictions within the ATMS.

Table 4.5 - Typical ATMS Vendor Modules

	Vendor 1	Vendor 2
Traffic conditions (congestion, average speeds);	Long list of intersection Measures of effectiveness, but not probe vehicle.	Travel time and includes historic comparison. Able to integrate Bluetooth device as well for un-signalized roadways
City vehicle locations via AVL.	No module from this vendor. Common feature with fleet management software.	No module from this vendor. Common feature with fleet management software.
Signal Performance	Arrival distribution (Purdue Coordination Diagram), split failure analysis, detector performance/failure, and cycle performance	Similar, long list of MOE's. Includes and heat diagram and traffic volume counts.
Incidents (detection, response, manage, close);	Provides management, priority service for emergency vehicles.	No module
Status of signals, detectors, and other ITS infrastructure - maintenance	Web based GIS, inventory assets maintenance status	Also GIS based, includes trouble ticket and dispatch information.
CCTV Management	Module with map and icons for easy selection.	Module with map and icons for easy selection.
Work zones (location, type, duration;	No module	No module
Maintenance and snow removal vehicle locations and status;	No module	No module
School flashers; RWIS and High Water	No module	No module

Communications to the VMS or PCMS will be via wireless communications. Private and cellular wireless options are discussed in Section 4.9.2 on page 4.19 As discussed the 700MHz band would be licensed through the City public safety radio licensing administrator, which is a relatively quick and no-cost process. This band is set aside for public safety applications including ITS with sufficient bandwidth.

Monitor Automated Vehicle Location (AVL) information on city vehicles. This is desired to track asset location to support real-time dispatching and also to perform analysis. AVL may be either part of a larger subsystem that includes other monitoring and reporting features unique to a particular fleet operation, such as snow plows, or may be generic location tracking on a GIS map such as the ATMS.

Tracking mobile assets is typically best done using cellular communications. Future 5G services, expected to start by 2021, will provide better capabilities. A virtual private cellular connection to the central IT network with proper firewall security provisions will be required.

Manage dispatching of Public Works vehicles. Dispatching may be a fully-automated, semi-automated or completely manual process depending upon the fleet size and capabilities desired. Fully and semi-automated solutions typically have Computer Aided Dispatch (CAD) system along with Automated Vehicle Location (AVL) that records activities and can report on key performance metrics. The CAD/AVL system would be supported using cellular communications. Manual dispatching may be as simple as a two-way voice radio with all dispatching and maintenance activities manually recorded.

DASH operates a bus transit Computer Aided Dispatch and Automatic Vehicle Location (CAD/AVL) system provided by Clever Devices for all its fixed route and Old Town trolley revenue vehicles. Communications is via T-Mobile 4G cellular using a virtual private network (VPN) connection over the public Internet to communicate with CAD/AVL servers in the City.

Monitor real time conditions, primarily via Conditions Map. The Conditions Map, discussed in the previous section, is the primary ATMS interface graphically representing all the relevant transportation data using a geolocated map interface. A dashboard may accompany the conditions map and would display key performance metrics by which system users may assess performance. Different dashboards may be displayed for different audiences (i.e., senior staff, operations, maintenance).

4.10.4 Future Operational Needs.

Physical Plant. The physical features of the current Traffic Management Center at 2900 Business Center Drive are adequate for the foreseeable future. There is adequate room in the Transportation Division offices to host many planners, managers, liaison personnel and other staff that could be expected during an emergency. The HVAC is expected to be adequate, and there is room for cots and two showers to accommodate continuous operations. The TMC has a 30 kVA UPS which acts as a bridge to a natural gas generator.

FHWA Guidance: Summary of Staffing Needs

Position	201 to 500 Traffic Signals
Traffic Signal Engineer	2 to 5
Traffic Signal Analyst/Technician	1 to 3
ITS Engineer	1
Traffic Signal Maintenance Technician	7 to 17
Electronic Specialists	2 to 4
TMC Operators	2 to 4
Public Relations Coordinator	1

Source: FHWA Traffic Signal Timing Manual, Extract of Table 8-2

Figure 4.4 – Recommended TMC Staffing.

Although 2900 Business Center Drive is adequate, a contingency plan should be made to use an alternate location in the event the primary location is not functioning. A good option is the Colvin Street Traffic Engineering field office. A Virtual TMC and the ability to duplicate the TMC monitoring and control at another Operations Center are needed.

Staffing. The TMC is currently manned by Traffic Engineering Division personnel. Including managers, there are 5 traffic section staff. Most weekdays staff will watch over conditions and monitor news reports while performing other work. In this manner, the TMC is active 5 days a week for 12 hours. During emergencies, other city employees are brought in to help staff the TMC on two 12 hour shifts providing 24 hour coverage.

FHWA guidance[8] for operating over 200 signals is 2 to 4 dedicated TMC operators and 14 to 31 other field and offic personnel. The City current operates with no dedicated TMC operators and only 12 other field and office personnel. In order to performed approved projects and meet the initiatives of this Master Plan the City will need additional staff.

The most critical, immediate need is the ITS Engineer. This person will provide support to the implementation of the two approved projects, implement TSP and Adaptive Traffic Signal Control. Without such a dedicated resource project implementation will be performed ad Hoc by staff that have full time responsibilities operating and maintaining the current signal system.

To the right is a recommended Organization Chart that will serve Traffic Engineering Division during normal operations (brown) and additional personnel needed during incidents and emergencies (light orange). Depending on the size of the incident or emergency, the incident staff may come from the normal operations staff. For example, the Incident Manager may be the same person as the Operations Manager. However, during longer term emergencies, additional staff is needed to maintain 24 hour TMC operations.

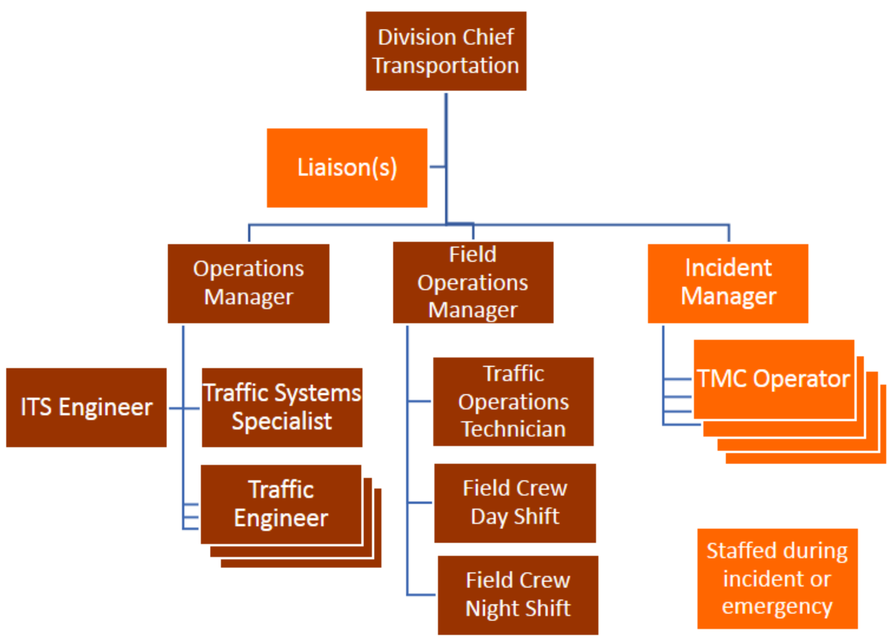


Figure 4.5 – Organization Chart. Lighter orange boxes indicate additional functions during incidents or emergencies.

[8] US Department of Transportation, Federal Highway Administration. Traffic Signal Timing Manual, Chapter 8: Signal Timing Maintenance: Operations and Monitoring. https://ops.fhwa.dot.gov/publications/fhwahop08024/chapter8.htm#8.4.

Communications. Communications to other Operations Centers is needed. Currently communications with other Operations Centers is via phone, text and email. Internet applications such as VDOT's Lane Closure Advisory Management System (LCAMS), 511 and the Regional Integrated Transportation Information System (RITIS) are also available to share information.

Connections to other Operations Centers

1. DASH
2. City 911
3. City EOC
4. VDOT Northern Region Operations
5. WMATA and Fairfax County Connector
6. Other jurisdictions (i.e. Arlington Co.)

However, secure, direct communication is needed as described in the 4.9 Communications. City Operations Centers – DASH, 911 and the City EOC should be over the City's IT network. Communications to VDOT NRO, WMATA, Fairfax County Connector and other jurisdictions can be performed over the NCR Net.

Virtual TMC. The vision of the Conditions Map and in virtual space is possible with current technology. The primary concern of a Virtual TMC is security, especially if some control of signal or other devices is included in the Virtual TMC. The Virtual TMC could be data and the conditions map only, and control features could be offered only where direct and closed communications are possible. Direct connection via the fiber network is a closed network.

The City should require some level of secure Virtual TMC in the selection and procurement of the ATMS.

4.11 Parking Management

For the City, Advanced Parking Management Systems (APMS) will have the primary objective of helping visitors to the City find parking spots quickly to enhance the visitor's experience. APMS will also benefit commuters; however, the City is committed to using ITS technologies to increase transit and decrease Single Occupancy Vehicle (SOV) use.

APMS can include detection or spaces and traditional traveler information systems. These systems are in use at airports, parking garages and other terminals. Recently many Cities have adopted web enabled systems that provide parking space information. These systems inform the visitor on the pay status of spaces. Spaces that are not in a pay status are likely to be vacant, conversely spaces that are in a pay status are likely to be occupied.

The metered on-street parking could be monitored for payment status. City parking meters currently have electronic payment and pay by phone capabilities. There are apps that allow visibility of which spaces are in a paid for status. The City parking garage detection entering and leaving provide an easy method to estimate availability. Additional detection for the reserve spaces and handicap spaces is necessary to provide a precise availability.

APMS is very relevant for the Old Town Area. The Old Town Area Parking Study (OTAPS) made the goals below for improving parking management in their study area. These goals serve well for other areas that have a high density of commercial and retail uses in the City:

5. Encourage short-term visitors to park in metered areas rather than residential blocks;
6. Encourage long-term visitors to use transit and park in off-street garages and surface lots;
7. Preserve parking on residential blocks for residents and guests;
8. Encourage compliance at meters and in residential parking districts.

Metered, on-street electronic payment that is then connected to a web enabled app that will allow visitors to view metered parking and is in keeping with the goals of the City.

4.12 Information Devices (RWIS, Variable Message Signs, Beacons)

4.12.1 Road Weather Information System (RWIS)

Road Weather Information System (RWIS) is a network of atmospheric and pavement sensors located along the highway system to provide accurate real-time road weather information. The system consists of four components: a collection unit comprising atmospheric and pavement sensors, communications device and media to transmit the data back to a central processing location, remote processing unit for storing and processing this data, and information dissemination.

Within the City, fixed location RWIS are useful for bridge and roadway overpasses where early freeze warnings will be beneficial. These bridge locations are usually associated with weather related high fixed object and run-off the road accidents. The City's 11 RWIS units are located on overpasses or key intersections (map on page 2.19).

Information collected by each station consist of:

- ambient air temperature
- relative humidity
- atmospheric pressure
- wind speed and direction
- visibility situation
- precipitation occurrence
- precipitation accumulation
- surface temperature
- snow depth
- stream water level

The RWIS may be used to guide roadway treatment and snow removal. If it is used in conjunction with an electronic sign, the RWIS may be used to automatically warn motorists of adverse conditions.

RWIS sensor technology and communications devices have been miniaturized allowing mobile, roving use. Fleet vehicles such as transit, snow removal, maintenance and EMS can be roving RWIS stations. To be effective, cellular or wireless communications would be needed to transfer the sensor data between vehicles and the Traffic Management Center. Additionally, data storage and processing would be required to aggregate and convert the raw feeds into useful information.

Additional RWIS were not discounted by the Stakeholders, but not seen as a high priority. Additional RWIS should be placed after an evaluation of the existing RWIS stations.

If RWIS were to be expanded, crash history should be used to provide additional information. The map below shows crashes is which the weather conditions was either snow or hail. The locations circled in red are good candidates for an RWIS. The City may also consider supplementing the fixed stations with mobile units which provide roving data on the health of the roadway network. A balance between fixed and mobile units will likely provide the City the coverage it needs at a significantly reduced cost.

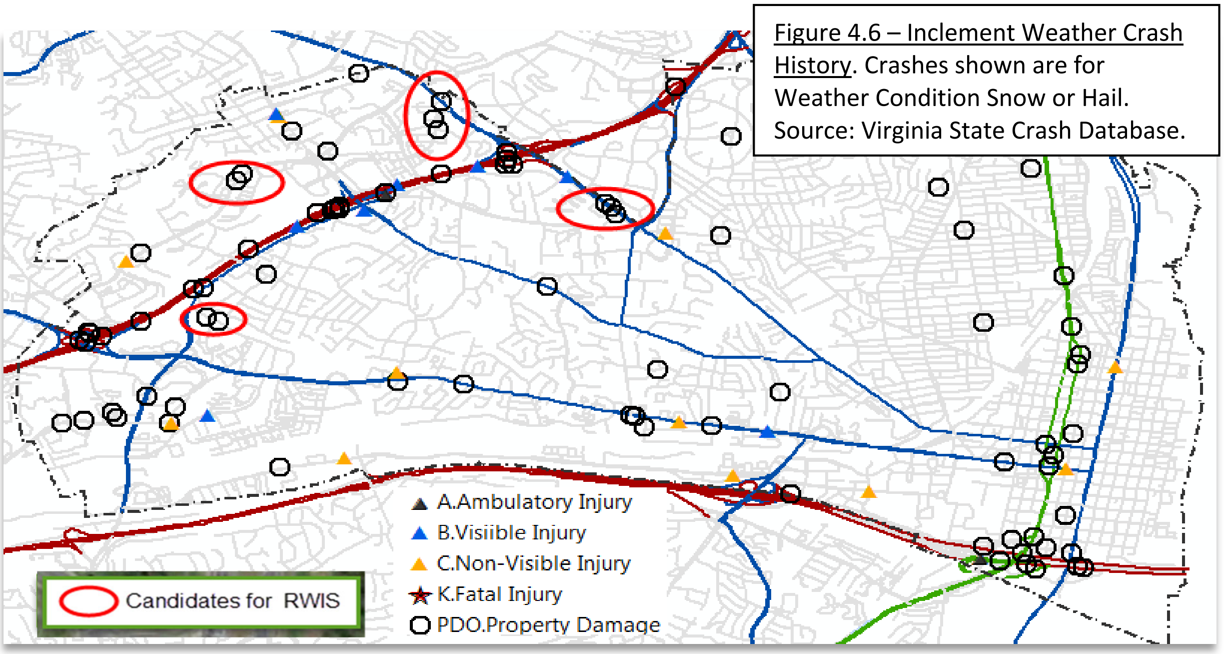


Figure 4.6 – Inclement Weather Crash History. Crashes shown are for Weather Condition Snow or Hail. Source: Virginia State Crash Database.

4.12.2 Variable Message Signs

For the purposes of this discussion, Variable Message Signs (VMS) are changeable signs that have a permanent location and are separate from Portable Change Message Signs (PCMS). This discussion focuses on fixed VMS as they are part of the permanent infrastructure.

The use of these signs is numerous and the following are the acceptable VDOT messages[9]:

1. Traffic Incident Situations
2. Construction and Maintenance Activities
3. Display of Future Roadwork
4. Adverse Weather, Environmental, and Roadway Conditions
5. Other Sources of Traveler Information
6. Special Events
7. Display of Future Special Events That Adversely Affect Travel
8. Display of Travel Times
9. Displaying Messages for Other States or Transportation Agencies
10. Emergency Messages
11. Ozone Advisory Messages
12. Safety Campaigns
13. VDOT project public meetings.

[9] VDOT Traffic Division, Changeable Message Sign (CMS) Usage Procedure, 2004

VMS are common in northern Virginia on major roadways. These signs are often mounted on large structures that are not suitable for an urban city scape. However, VMS come in many sizes and technologies and some are of proper scale for urban areas.

Of the 13 acceptable uses shown in the VDOT guidelines, few warrant a permanent sign for the City. “Special Events” to inform residents or tourists of City activities is a use that would warrant a permanent VMS. “Travel Times” is a common message on area VMS, however is not as relevant on City Roadways. Once a vehicle is on a City arterial, a common recourse if they become aware of congestion is to seek an alternate route. Most often these alternate routes are smaller residential roadways.

There is a need for temporary VMS. Most of the uses shown above can be economically served with Portable Change Message Signs PCMS. Power for PCMS can come from solar charged batteries or from a generator. Communications are from wireless.

The City could make effective use of a VMS in an area where the message could both inform City residents of events and provide information about incidents or other temporary events. Outside of this dual use, the City is more economically served with PCMS.

5 Future Deployments

5.1 Overview

"Envision walking out of your front door and down a streetscaped sidewalk, safely crossing the street at a well-marked, signalized intersection that made you feel like you, the pedestrian, had priority…. You board the transit vehicle, settle into a comfortable seat, and check on your estimated arrival time on the variable message board at the front of the vehicle…. You watch the bicyclists commuting safely along the bicycle lanes dedicated along this corridor and pedestrians sipping their morning coffee on the landscaped walkway, and before you know it, you are at your destination — sooner than if you had decided to drive yourself." Extract from introduction of City of Alexandria Master Plan.

The City of Alexandria has long envisioned an attractive, well connected multimodal transportation system. The Transportation Master Plan, cited above from 2008, is a plan to create a multimodal city supported by technology.

Since 2008 the City has made steps towards this vision. Automated Vehicle Location (AVL) on transit vehicles, new fiber networks, electronic parking meters, Roadway Weather Information Systems and the Transportation Operation Center are examples. The previous chapter plans additional investments to continue this trend.

There are transformational technologies that the future will bring. Connected and autonomous vehicles are in our future. The When, What, Where and How has not been decided, and there are many unanswered questions and obstacles. Nonetheless, numerous trials have shown that the technology is available. The Google self-driving car has been in testing since 2009, and as of June 2016, has logged a total of 1,725,911 mi[10] in autonomous mode.

The future also promises to bring improved efficiencies of city services and provide additional insights of collected data made possible via the Internet of Things (IoT) and the Smart Cities initiatives. Smart street lights which may also detect traffic and parking patterns and smart parking systems to improve parking space utilization and reduce circulation and congestion are all possible applications. The Virginia Smart Communities (VASC) Working Group has been established to equip Virginia's communities with the resources, support, and tools to become smart and sustainable. One initiative seeks to combine federal, state, city and private data into a single analytic framework – an open innovation platform that all cities can access with the state providing technical support, best practices and easy onboarding.

The vision of future transportation from 10 years ago has not changed significantly. Transit, bike and pedestrian modes will all be protected, connected and easily used. Autonomous vehicles will be as convenient, but safer and more efficient than single occupancy travel. Focused information will be provided to travelers through their own devices.

This chapter discusses how future ITS deployments need to prepare for a Smart City future.

[10] Google Self Driving Car Project, Monthly Report June 2016.

5.2 5.2 Connected and Autonomous Vehicles (CAV)

5.2.1 Overview

It is well recognized that CAV will bring widespread changes to transportation. This recognition has led to participation from a full spectrum of entities. University researchers, automobile manufactures, vendors of transportation technologies, Uber, Google (now Waymo) and many others are all developing and testing CAV solutions.

Recently, the landscape for automated vehicles has changed considerably. Just five years ago, predictions on the advancement of automated vehicles placed the onset of automated vehicles out to the 2025-2035 time horizon; now, levels of automated vehicles are currently on the market. "Highly automated" levels of automation, which enable hands free driving, are anticipated as ready for market over the next three years[11] [12] [13] [14].

Here is a summary of when industry leaders are saying their products are coming to market to support autonomous vehicles:

- Audi-2020
- Delphi and MobilEye- 2019
- Ford-2021
- Volkswagen-2019
- GM- 2020
- BMW-2021
- Toyota-2020
- Tesla-2018
- Honda – 2020

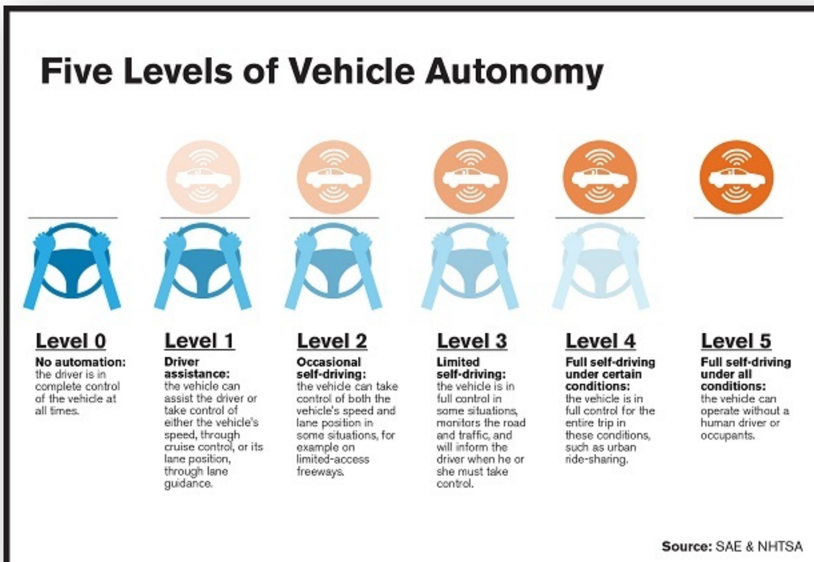


Figure 5.1 – SAE and NHTSA Levels of Vehicle Autonomy

5.2.2 AV Technologies

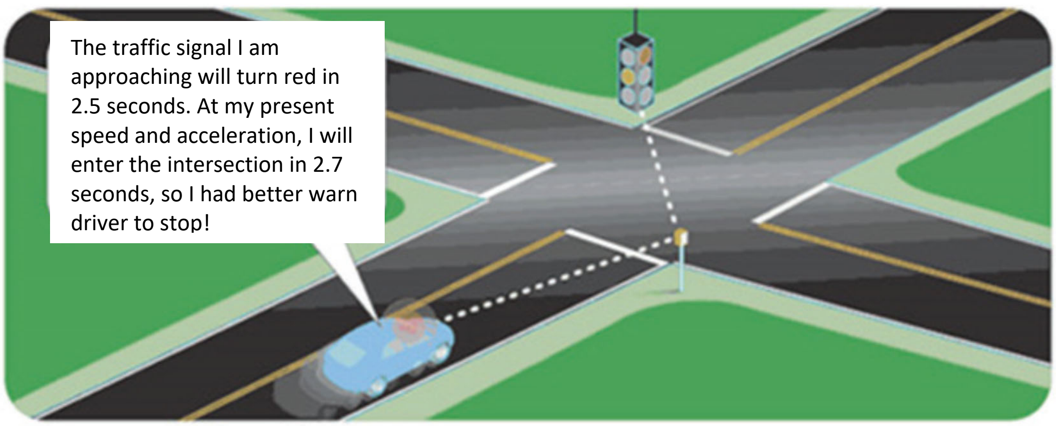
Geolocation: It is important for all automated vehicles to understand where they are and the rules (e.g. speed limits, lane restrictions) that apply. Typically, electronic devices that seek location information do so through use of global positioning system (GPS). Differential GPS and map based Dead Reckoning (the process of calculating a position by using a previously determine position) are used supplement the satellite system. See Appendix for a fuller description of AV Technologies.

[11] https://spectrum.ieee.org/cars-that-think/transportation/self-driving/nvidia-ceo-announces
[12] https://www.wsj.com/articles/gm-executive-credits-silicon-valley-for-accelerating-development-of-self-driving-cars-1462910491
[13] https://techcrunch.com/2016/10/13/renault-nissan-ceo-carlos-ghosn-on-the-future-of-cars/
[14] https://electrek.co/2017/04/29/elon-musk-tesla-plan-level-5-full-autonomous-driving/

LIDAR: As many as twelve LiDAR sensors may be installed on a vehicle to allow it to sense objects in all directions. These devices create a rich, detailed data set that represents the dynamic and stationary elements in the field of view (FOV) of the vehicle. See Appendix for a fuller description of AV Technologies.

Video: Another technology is the use of high definition cameras with video analytic technology. The video analytic engines, now coupled with cameras, allow for vehicles to interpret objects as they appear in their field of vision. This provides information on the classification of the object, (i.e. determining if the object is a pedestrian, bicyclist, car, or stationary object).

Collision Avoidance: Advancements in connected vehicle communications have resulted in the development of collision avoidance systems for intersections, otherwise known as Cooperative Intersection Collision Avoidance Systems (CICAS). Intersection collision avoidance systems use both vehicle-based and infrastructure based technologies to provide information to a vehicle approaching an intersection on the status of the traffic signals at that intersection



Signalized Intersection: While most automated vehicles used in public spaces today do not communicate or operate in concert with signalized intersections, the automated transit vehicle manufacturers intend to utilize DSRC as a primary means of communicating with vehicles as they progress through an intersection. This will provide the vehicle with the information needed to understand the signal phase, and timing (SPaT) at any given time. The manufacturers would supplement this primary means of knowing the state of the intersection with video recognition, which can allow the vehicle to see the color of the light as well as determine if there is anyone running a light.

Legislation: Legislation regarding automated vehicles has been done through a patchwork of different approaches across the country. _In early 2017, the USDOT published a guidance document that provides States and other municipalities a more common framework. The document provides guidance in twelve (12) areas: system safety, operation design domain, object and event detection and response, fallback (minimal risk condition), validation methods, human machine interface, vehicle cybersecurity, crashworthiness, post-crash Avoidance Detection System (ADS) behavior, data recording, consumer education and training, and federal, state, and local laws.

5.2.3 CV Technologies

The landscape for connected vehicles is advancing quickly with the National Highway Traffic Safety Administration (NHTSA) issuing a Notice of Proposed Rulemaking in December 2016[15]. The rulemaking proposed a rollout schedule to mandate the use of DSRC in new light vehicles. The final ruling is scheduled to be issued in 2019, followed by a phase-in period in 2021, and compliance mandating Vehicle-to-Vehicle (V2V) communications in all new vehicles required by 2023.

Although it has since been retracted, the Federal Highway Administration (FHWA) issued a Vehicle-to-Infrastructure (V2I) Deployment Guidance document on January 2017[16]. While the document is no longer officially in the public record, there are very helpful reference "tools" that were developed as part of the guidance that can be found at the USDOT's ITS Joint Program Office (JPO) website, https://www.its.dot.gov/v2i/.

Through the JPO, the USDOT has provided leadership for those who are interested in implementing V2I, and are encouraging deployments, but public agencies are not required to implement V2I technology or applications. The USDOT has recommended eight (8) V2I safety applications for focus and consideration for initial implementation: red light violation warning, curve speed warning, stop sign gap assist, reduced speed zone warning, spot weather information warning, stop sign violation warning, railroad crossing violation warning, and oversize vehicle warning[17].

To help in their part of the encouragement of deployments, AASHTO established the Connected Vehicle Signal, Phase and Timing (SPaT) Challenge to deploy DSRC infrastructure in at least one corridor of 20 signalized intersections in each state by January 2020. SPaT is a broadcasted message that indicates the current state of an intersection and can be used to enable a number of safety applications such as intersection collision avoidance. Virginia VDOT smarter roads data portal (http://smarterroads.org).

The next generation of cellular communication, 5G, is currently being developed by chip manufacturers, and designed by telecom companies. Conceptually, 5G is purported to have significantly lower latency issues than the current 4G LTE system. This decrease in latency makes 5G a possible consideration in implementing an alternative to DSRC for V2I communications. The automotive industry is split between DSRC and 5G, with General Motors (GM), Toyota, Volkswagen (VW), and many tier one suppliers backing DSRC; while Audi, BMW, Ford, and others support cellular Vehicle-to-Everything (V2X) through the 5G Automotive Association (5GAA)[18].

Additional initiatives by automobile manufactures, government pilot studies and telecommunication companies are in Appendix C: CAV Technologies.

5.2.4 Policy and Planning for Connected and Autonomous Vehicles (CAV)

The long list of entities that will have a role in shaping and facilitating the benefits of CAV include Federal, State and local governments. NCHRP Report 845, *Advancing Automated and Connected*

---

[15] https://www.transportation.gov/briefing-room/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands

[16] https://www.fhwa.dot.gov/pressroom/fhwa1703.cfm

[17] https://www.its.dot.gov/cv_basics/pdf/Readiness-of-V2V-Technology-for-Application-812014.pdf

[18] http://www.autoconnectedcar.com/2017/12/enhanced-d2d-will-transform-more-v2v-5g2v-v2x-for-autonomous-cars/

Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies[19] was released in late 2017 and lists strategies and actions that different levels of government can take.

Chapter 3: Policy and Planning Strategies lists a number of strategies. Those that involve local governments, and the potential for Alexandria are listed below:

Table 5.1 – NCHRP Report 845 Strategies

NCHRP Report 845 Strategy	How Strategy Applies
Enact Legislation to Legalize AV Testing: The strategy aims to accelerate the development, adoption and implementation of AVs and CVs by enacting legislation to establish the legality of AV testing. Page 22.	For Alexandria, this would entail enacting City Codes to allow pilot studies on City Streets.
Enact Legislation to Stimulate CV or AV Testing Strategy: The strategy aims to accelerate the development, adoption, and implementation of AVs and CVs by enacting legislation to directly fund testing for CV or AV development. Page 25.	This strategy would be to fund SPaT or other pilot project.
Increase Public Awareness of Benefits and Risks Strategy: The strategy seeks to increase public awareness of benefits and risks of CV/AV technologies through education, training, communication, and outreach. Page 35.	Outreach will encourage use where desired Outreach and prevent unrealistic fears or optimism.
Subsidize Shared AV (SAV) Use Strategy: This strategy intends to subsidize SAV services to ensure alternatives to individually owned AVs and to support ridesharing and transit services, including paratransit. Page 41.	Efforts by Uber are underway to create a driverless taxi-like service. This subsidy is intended to help create an alternative to the current Uber model.
Implement a Parking Cash-Out Strategy: The strategy uses parking cash-out benefits as an economic incentive to encourage individuals to use SAVs. Page 49.	In the report, this strategy is listed as an employer plan.

[19] Transportation Research Board, 2017. *Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*, NCHRP Research Report 845.

Table 5.1 – NCHRP Report 845 Strategies (Continued)

Implement Land Use Policies and Parking Requirements: The strategy is to implement and use policies and parking requirements to support the market penetration of SAVs at transit nodes and other activity centers. Page 53.	Alexandria, as a promoter of multimodal transportation, has policies that may not need much change to promote SAV.
Subsidize CVs: This strategy seeks to encourage the adoption and market penetration of CV technology by providing subsidies for CV equipment. Page 73.	To be considered after 2nd Strategy – Pilot.
Invest in CV Infrastructure: This strategy aims to provide investment in CV infrastructure to encourage the development and adoption of AV and CV technologies. Page 76.	To be considered after 2nd Strategy – Pilot.
Grant AVs and CVs Priority Access to Dedicated Lanes: This strategy grants AVs and CVs priority access to dedicated lanes to promote market development. Page 78	Combine with Pilot.
Grant Signal Priority to CVs: The strategy grants CVs, including transit and commercial vehicles, signal prioritization to accelerate market penetration. Page 81	Combine with Pilot.
Grant Parking Access to AVs and CVs: This policy strategy grants AVs and CVs priority parking access to accelerate the market development. Page 83.	Combine with Pilot.
Implement New Contractual Mechanisms with Private-Sector Providers: The strategy aims to establish new contractual mechanisms with private-sector providers, including shared data arrangements, to incentivize the development of a viable marketplace for AV and CV technologies. Page 85.	This strategy offers unknown benefits. The new ITS coordinator should be assigned the task to identify Private-Sector opportunities.

Although all the NCHRP 845 strategies shown are relevant for Alexandria, none are required immediately. However, the City can identify City Code or State Statue that limit CAV, begin implementing pilot studies, adding connected vehicle infrastructure and begin conducting public outreach.

5.2.5 CAV Recommendations

Any transportation planning should consider that highly automated vehicles will be market ready by 2020[20][21]. Population penetration estimates are difficult, but a review of most in the industry anticipates wide availability of fully autonomous vehicles by 2025[22]. With some automated shuttle providers stating the need for DSRC to implement communications between vehicles and signalized intersections, planning should thus consider preparing signalized intersections for DSRC communications in corridors where automated shuttles may be a transit option.

Appendix C: *CAV Technologies* lists additional best practices and recommended activities.

- Conduct regulatory review to fully understand what City or State Code impedes City CAV pilot projects.
- Conduct pilot of an CAV corridor within the City and for eventual CAV deployment throughout the region. This pilot will need to be planned with the VDOT CV group. A shuttle service between high density nodes or transit hubs would provide a good pilot.

  A good site for the region is Eisenhower Avenue or Potomac Yards. Both locations would serve Metro rail stations, and both have newer roadways with good access control.
- Work with the VDOT CV group to plan for eventual deployment of CV technology and applications within the City based on lessons learned from the VCC initiative, infrastructure developed for the collection, dissemination of CV data, and development of common applications.
- Complete Phase V Fiber deployments and extend broadband communications capability to all signalized intersections and ITS devices as recommended in Chapter 4.
- Replace traffic signal controllers and roadside cabinets as recommended in Chapter 4.
- Plan uninterrupted power supply (UPS) for intersections where DSRC radios may be deployed.

5.3 Bike and Pedestrian Applications

5.3.1 Overview

The City of Alexandria is committed to bike and pedestrian transportation. To "*Sustainably plan for growth by encouraging transit, biking and walking and reducing single-occupancy vehicle (SOV) driving*" is a guiding principle from the Transportation Master Plan. Furthermore, the City's Complete Streets Design Guidelines has focused strategies in support of this guiding principle. It is a priority for future ITS technologies to improve safety and accessibility of bike and pedestrian travel.

However, it is unclear as to how future ITS developments – such as Autonomous Vehicles - will integrate bike and pedestrian travel. There is an argument that they are not compatible; that bikes will be able to

[20] http://fortune.com/2017/09/13/gm-cruise-self-driving-driverless-autonomous-cars/
[21] https://www.forbes.com/sites/adp/2017/12/15/small-business-hr-and-hiring-challenges/#3f681adc1049
[22] https://assets.kpmg.com/content/dam/kpmg/pdf/2016/06/id-market-place-of-change-automobile-insurance-in-the-era-of-autonomous-vehicles.pdf

disrupt the flow of traffic at will, or that bikes and pedestrians simply cannot be connected. A counter argument is that Connected and Autonomous Vehicles (CAV) will improve vehicle throughput and free up roadway lanes for non-motorized travel.

The City is dedicated to reducing the number of vehicles on their roadways and lowering the demand for parking. When successful, the City's Complete Streets concepts will be easier to implement. Complete streets, will in turn encourage bike and pedestrian uses. This section identifies many techniques and technologies to improve bike and pedestrian safety and capacity.

Although each technique and the technologies identified are appropriate for specific situations, improved detection is required for each.

5.3.2 Technology and Applications Options

The potential for meaningful ITS technology for bike and pedestrian travel will increase with a) improvements in the pedestrian, bike and trail network and implementation of Complete Streets and b) further progress with detection and Connect and Autonomous Vehicles (CV/AV) technologies. Improving the pedestrian and trail network is underway with implementation of the Complete Streets guidelines. This section will emphasize additional street improvements and potential ITS technologies.

Alexandria Complete Streets Design Guidelines: Main Street Example

<u>Signal Improvements for Bike and Pedestrian travel</u>.

The Complete Streets Design Guidelines proposes street treatments to create safe, continuous bike and pedestrian routes. In addition to these improvements, there are many treatments in use that assist bikes and pedestrians through signalized intersections:

Separate bicycle signals. In a study conducted by FHWA "Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices" a number of different innovations in use that relied on separate bike signals. [23] Shown is signal in San Luis Obispo, California.

Fully protected bicycle phase. The FHWA study found a number of high bicycle locations that promoted a "green wave" of bicyclists. In some applications bicycle detection was used to hold and create a platoon of bikes that were given treatment similar to a platoon of vehicles.

[23] Libby Thomas, Paul Ryus, Conor Semler, Nathan J. Thirsk, Kevin Krizek, Charles Zegeer (May 2015). Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices. Report Number FHWA-15-051. Federal Highway Administration Office of International Programs Washington, DC 20590

Pedestrian and Bicycle scramble phase. A variation of a fully protected bike phase, in the scramble phase all bike and pedestrian movements receive a green signal, while all vehicles have a red signal. Where used, bike or pedestrians gave way to each other without incident (page 24).

Green LED lane lights (source: "Delivering Connected Bike and Pedestrian Travel"). Green lane lights in the pavement on a separate bike lane provide a message like a "pedestrian countdown". The intent of the lights is to prevent the bicycle from entering the intersection on red.

Bicycle Signal Priority. The FHWA study found in Victoria Province, Australia signal treatments that used radar bike detectors to extend the crossing time, or provided bikes a leading signal (page 25).

Detection Improvements. Detection of bikes and pedestrians by the surrounding infrastructure is necessary for many innovations. The basic detection technologies have been adapted and in use for both bikes and pedestrians.

- Radar
- Wireless Magnetometer
- Infrared
- Video
- Inductive Loops.

> "One suggestion is simply to make cars, bikes, pedestrians (and presumably household pets) part of the Internet of Things so everyone in the vicinity can "talk" to each other digitally in real time. While that may seem like a swell idea to some, it opens up all sorts of concerns about privacy and hacking. There may be many people who would be thrilled to get themselves fitted with a subdural RFID device, but most would find the idea far less appealing..." *Steve Hanley, CleanTechnica.*

As the City's Complete Streets Guidelines are implemented these detection technologies will be easier to use to focus on bikes and pedestrians and to implement the signal features discussed above.

One additional method of detection is via smartphones, smart watch or some future device carried by all. This detection, often to referred to as "The Internet of Things" would *connect* people not inside a vehicle. Although it is too early to tell if this is a means to not only detect but to connect bikes and pedestrians, it is important not to preclude this method. The Text Box above describes a view, and the potential privacy issue, related to Internet of Things[24].

As with the rest of this Plan, the Complete Streets Design Guidelines and ongoing efforts there is nothing to preclude using "The Internet of Things". The improvement of the City's fiber communication networks and activities in the previous Chapter all support a "Internet of Things" approach.

One additional method to detect bikes and pedestrians is via vehicles. Connected vehicles could detect the roadway, and adjoining sidewalks and path areas. Currently radar is widely used to avoid collisions.

---

[24] Steve Hanley (August 2017). "Bicycles & Autonomous Cars Are On A Collision Course". https://cleantechnica.com/2017/08/21/bicycles-autonomous-cars-collision-course/

5.3.3 Recommendations

1) The City's current investments to implement the Complete Streets concepts, installing fiber communications, and updating signal connections all support a future in which bikes and pedestrian travel will be improved with ITS innovations.
2) Unlike vehicles, it is unlikely that there will be a means to create "connected" bikes and pedestrians. **As such it is important to install active bike and pedestrian detection**. A Systems Engineering approach should be taken to determine which of the technologies is optimal.
3) In addition to completing planned improvements the City should continuously evaluate technical innovations as they relate to bikes and pedestrians.

5.4 Putting it All Together – Smart Cities

Smart Cities in which digital technology from connected vehicles, infrastructure, government agencies, residents and businesses combine to optimize and inform.

5.4.1 Overview

Smart Cities has developed into a world-wide movement that utilizes the advancement of digitization, communications, sensors and data analytics to make improvements to city functions. The basic idea is that smart cities leverage and integrate technology to make people's lives better. While the concept of a smart city started to percolate in the early 2000s along with the Internet boom, we began to really grasp the concept when places like Masdar City in Abu Dhabi were being planned and built around 2010—a utopian world where renewable energy and "personal rapid transit" pods prevail.

In fact, smart cities have found their way into current legislation. The Fixing America's Surface Transportation (FAST) Act is the transportation reauthorization bill that was signed into law last December. The bill includes a $60 million per year Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program to develop advanced technologies in transportation. Of the many areas that this program is interested in funding, one of these is the integration of ITS with the Smart Grid. There is also a research initiative that has been established for a Smart Cities Transportation Planning Study. The Smart Cities Council https://smartcitiescouncil.com provides various resources to promote livability, workability, and sustainability through smart city technologies.

Immediately after this bill was authorized, the USDOT issued a Notice of Funding Opportunity "Beyond Traffic: The Smart City Challenge." Director Anthony Foxx marketed this heavily and called for any city to share ideas and promote innovations to address some of the most pressing challenges they're facing today. The Smart City Challenge will demonstrate and evaluate a programmatic, integrated approach to improving surface transportation performance within a city, integrating this approach with other smart city domains like public safety, public services, and energy. Essentially, the USDOT is interested in addressing how transportation data, technologies, and applications can be integrated with existing urban infrastructure to address transportation challenges.

Seventy-eight cities responded. Seven finalists were announced at the South by Southwest (SXSW) festival in Austin: San Francisco, Portland, Denver, Austin, Kansas City, Columbus and Pittsburgh. Columbus was the final winner.

The City of Columbus won the $40 million USDOT grant and $10 million from Vulcan Inc. as part of the challenge and they were able to pull together an additional $90 million in pledges from local businesses during the application period[25]. Since being awarded the grant, the City of Columbus has received additional investments bringing their total to $500 million. Smart Columbus plans on using the funding to deploy 15 USDOT funded projects and four Vulcan-funded priorities[26]. The projects include an integrated data exchange, connected vehicles infrastructure, common payment system, multimodal trip planning, smart mobility hubs, smart street lighting, collision avoidance, mobility assistance, enhanced permit parking, event parking management, delivery zone availability, connected electric autonomous vehicles, truck platooning, oversize vehicle routing, and interstate truck parking. The expectation is that these projects will begin being deployed in mid to late 2018.

The City of Atlanta has just released an RFP on December 29, 2017, inviting businesses to partner on the city's next generation of smart city projects[27]. The RFP states that the City of Atlanta is experiencing large increases in population, visitors, and number of businesses. These increases are creating new challenges in handling street traffic, foot traffic, and data traffic. The City of Atlanta is looking to solve these challenges by implementing technological advances in fiber, wireless, sensors, big data analytics, and connected devices. The RFP highlights a desire to increase the fiber deployment from 50 route-miles to 150 route-miles, install smart lighting and smart utility poles, interactive kiosks, 5G small cells, smart traffic infrastructure, smart utility poles, smart fleet, increased Wi-Fi connectivity, and offer free public Wi-Fi. The City of Atlanta expects to pay for the projects with a $250 million infrastructure bond and that the improvements must create cost savings to help offset the costs.

The City of Dallas has been engaged in a number of smart initiatives. Through a public-private partnership the Dallas Innovation Alliance has deployed the first phase of a multi-phased smart city strategy in March 2017[28]. The first phase installed two blocks of smart streetlights, a digital kiosk, and environmental sensors that measure air quality and allergens. Phase two of the development includes public Wi-Fi, smart parking, and smart irrigation and expected to be deployed in early 2018. In another initiative the City of Dallas selected Ericsson on January 8, 2018 to install a smart cities traffic management system[29]. The system will improve sharing of data and video across city agencies, and eventually, across municipalities. The system will also give the City of Dallas the ability to analyze the data in real-time and use the information to control other systems.

The City of Sacramento in partnership with Verizon is implementing a number of smart services[30]. Sensors have been placed in city streets and cameras have been installed to help analyze traffic. Verizon has also announced they would be spending $100 million on infrastructure to provide Wi-Fi in parks and expand its fiber optic network. Sacramento will also be one of the first cities to have a Verizon 5G network.

---

[25] https://www.techrepublic.com/article/how-columbus-ohio-parlayed-50-million-into-500-million-for-a-smart-city-transportation-network/

[26] https://www.columbus.gov/smartcolumbus/projects/

[27] http://procurement.atlantaga.gov/wp-content/uploads/2017/12/FC-10262-Atlanta-SmartCity-Strategic-Infrastructure-Initiative.pdf

[28] https://dallasinnovates.com/game-changers-dfw-innovation/

[29] https://www.bizjournals.com/dallas/news/2018/01/08/city-ofdallas-chooses-ericsson-for-smart-cities.html

[30] https://www.fool.com/investing/2018/01/01/verizon-wants-to-help-build-city-streets-of-the-fu.aspx

The City of Hong Kong in China released their Smart City Blueprint on December 15, 2017[31]. The blueprint maps a five (5) year development plan to enhance the city in six major areas: mobility, living, environment, people, government, and economy. Some of the improvements include installation of traffic detectors in all strategic roads to provide real-time traffic information by 2020, publication of real-time information of public buses through mobile devices by 2018, facilitate trials of autonomous vehicles, use of remote sensors to monitor air pollution, and deploy 5G network by 2020.

The City of Jamshedpur in India is working on multiple IoT projects with Tata Communications Ltd[32]. They have been rolling out a specialized communication network called LoRaWANs (Low Power Wide Area Networks), this network will allow for smart city services such as smart metering and lighting. They have also installed storm and floodwater monitoring and water quality control sensors.

Fairfax County, VA, is also working on a countywide smart city strategy to "transcend silos and connect strategic initiatives." The county has already established several transformative programs – creating cross-departmental teams to achieve goals and uniting the public, private, philanthropic and academic sectors. The goal of its e-Gov initiative is to have a “government without walls, doors, or clocks”

Implications to transportation

It’s no surprise that the first government sponsored smart cities initiative was developed out of the USDOT’s JPO. ITS is essentially considered a smart cities solution for mobility. Smart cities initiatives consequently impact transportation the most of all the possible city focus points. This is in large part due to solution maturity and a well-defined systems engineering process to implementation.

5.4.2 Recommendations

Smart city initiatives are broad and typically encompass a wide range of city functions. Outside of federal seed grants, most of these initiatives include private investments in the form of public-private-partnerships (P3). These partnerships typically allow a private company to use public space for their own research and development efforts, improve their service offerings, or simply provide a form of branding and outreach. If there are willing partners, these types of investments can provide huge returns to a city. We are recommending that the City considers P3’s as potential source of funding for of advanced transportation solutions.

[31] https://www.opengovasia.com/articles/hong-kong-unveils-smart-city-blueprint-with-initiatives-in-6-areas-mobility-living-environment-people-government-and-economy
[32] http://www.livemint.com/Politics/2gxo1sC1GOCFlNlNTKED5J/How-Jamshedpur-is-becoming-a-smart-city.html

6 Implementation Plan

The City is implementing many of the elements recommended in Chapter 4: Near Term Deployments and Chapter 5: Future Deployments. They are also applying for additional projects (via Smart Scale and NVTA) for additional funds. This Implementation Plan correlates the timing of existing and future projects with existing and future funding.

The City has used a phased approach to implement fiber installation. To consolidate and ease procurement, we recommended expanding the Phase descriptions. As such we recommend the following Phases:

Phase I: Complete. Fiber Optic cable and conduit on Duke Street, Quaker, King Street, Seminary and North Beauregard, as shown in Figure 2.1.

Phase II: Complete Fiber Optic cable and conduit on US Route 1, Washington Street, Old Town portion of King Street and segments of Van Dorn and Beauregard. As shown in Figure 2.1.

Phase III: Design in procurement. 2019 / 2020.

1. CCTV and RWIS at 10 locations.
2. Connect signal controllers to Fiber Optic Cable placed in Phase I and other selected intersections (41 intersections).
3. Fiber Optic cable and conduit along portions of Eisenhower, Duke Street and Van Dorn.
4. Expand the Transportation Management Center (TMC) video wall and design and installation of real time conditions map.
5. Create asset inventory consisting of conduits, cable, copper locations, CCTV cameras, RWIS and major signal components. This task may be shared with Adaptive Phase I.

***Adaptive Traffic Control* Phase I: Upgrade ATMS, Begin Adaptive.** 2019 - 2021.

1. Create Communications Implementation Plan.
2. Add Fiber Optic cable, conduit and CCTV cameras to missing sections of Eisenhower Avenue.
3. Use Systems Engineering approach to select and implement Traffic Signal System (TSS), ATC controller and firmware, and Advanced Traffic Management System (ATMS) upgrades.
4. Use Systems Engineering approach to select and implement Adaptive Signal Traffic Signal Control (ATSC).
5. Select, purchase and install cabinets, controllers and detection. New detection will be for ATSC corridors.
6. Begin Adaptive signal control for one or more corridors.

Phase IV: Expand Fiber, ATMS and TSP. Planned 2020 /2021.

1. Connect signal controllers to Fiber Optic Cable placed in Phase III and at other selected intersections.
2. Extend Fiber optic cable to missing corridors in accordance with Communications Implementation Plan. Section 2 identified the following corridors:

   a. N Howard Street, W Braddock Road and western Seminary Road.
   b. Duke Street along the missing 2.0 miles.
   c. Mount Vernon Avenue and Braddock Road.
   d. Potomac Yard.
3. Complete fiber deployment to data center locations consisting of the TMC, City Hall, EOC, and DASH transit centers. This fiber will create a future backbone for DSRC deployment.
4. Add Transit Signal Priority (TSP) to King and Duke Street.
5. Further expand ATMS capabilities including Parking and asset/maintenance management, incident/event management, CAD incident data integration, further dashboards.
6. Pilot test of private wireless communications solution and DSL connections to traffic signal cabinet.

***Adaptive Traffic Control* - Phase II**

1. Expand Adaptive Traffic Signal Control to remaining corridors. Eight total corridors are planned for Adaptive Control. (see Table 4.1).
2. Extend broadband communications capability to all signalized intersections and ITS devices via GPON, DSL, Private wireless, Cellular 4G/LTE or Future 5G.
3. Further expand ATMS capabilities including Parking and asset/maintenance management, incident/event management, CAD incident data integration and other dashboards.
4. Using a Systems Engineering approach, perform upfront activities for passive Bike and Pedestrian detection.

Phase V – Further Expand Capabilities and AV Pilot. 2025.

1. Install Connected Vehicle Dedicated Short Range Communications (DSRC) RSU at key locations. DSRC will be used to broadcast SPaT data to vehicles and other users.
2. CAV test bed Planning along Eisenhower or in Potomac Yards. This activity will be coordinated closely with statewide efforts and based on DMV licensing/approvals, and may require roadway improvements to separate CAV vehicles from other traffic.
3. Implement Bike and Ped detection.
4. Further ATMS capabilities including CV application integration.

DASH Communication and Service Improvements. These improvements consist of upgrades to the existing Fare and Automatic Vehicle Locator system, a real time feed to DASH Operations Center and other improvements.

Transportation and Parking Technologies. These line items represent a broad range of planned procurements that include weather stations, emergency preemption, automated data collection, and backup power. Parking Technologies are expected to include parking sensors and parking information systems.

Funding Needs. The 12 recommendations from Chapter 4 correspond to a series of projects and procurements that are estimated to cost $39.7 Million. Fortunately, the City has been successful obtaining Congestion Mitigation and Air Quality Improvement (CMAQ), Northern Virginia Transportation Authority (NVTA) funding and Smart Scale Funding for some of these improvements. The shortfall is estimated to be $11.7 Million. Table 6.1 shows a summary of City CMAQ, NVTA, State and Federal Funding:

Table 6.1 Summary of Funding

ITS Element	Unfunded	Total
TSP Duke/RT 1		$910
TSP King/Duke		$1,195
Phase I-III		$8,206
Phase IV Fiber		$2,126
Phase V Fiber	$2,543	$2,543
ATSC		$14,676
Eisenhower Broadband		$1,000
Bike Ped	$4,950	$4,950
Other	$186	$186
Phase VI	$4,000	$4,000
Total	**$11,679**	**$39,792**

Summary. This Master Plan lists near and long-term deployments to continue Alexandria's ongoing ITS efforts and to prepare for future technologies. Many of the near-term deployments – such as Transit Signal Priority and Adaptive Traffic Signal Control - provide a bridge to emerging future technologies. These future technologies include Connected and Autonomous Vehicles and infrastructure for Smart Cities. The Plan consists of VI Phases, culminating in a Pilot of an Autonomous Shuttle in 2023.

The City has funds for many of the ongoing near-term deployments, however an additional $11.7 Million is needed to meet the full six Phases. The projects that comprise this $11.7 Million shortfall improve safety, ease congestion and promote economic development. They are good candidates for Northern Virginia Transportation Authority, Smart Scale funding and CMAQ grants.

This plan relies on our current knowledge of communication, signal control and traffic management technology. It also relies on our knowledge of existing and emerging travel patterns and demographics. As these elements change, so should this Master Plan.